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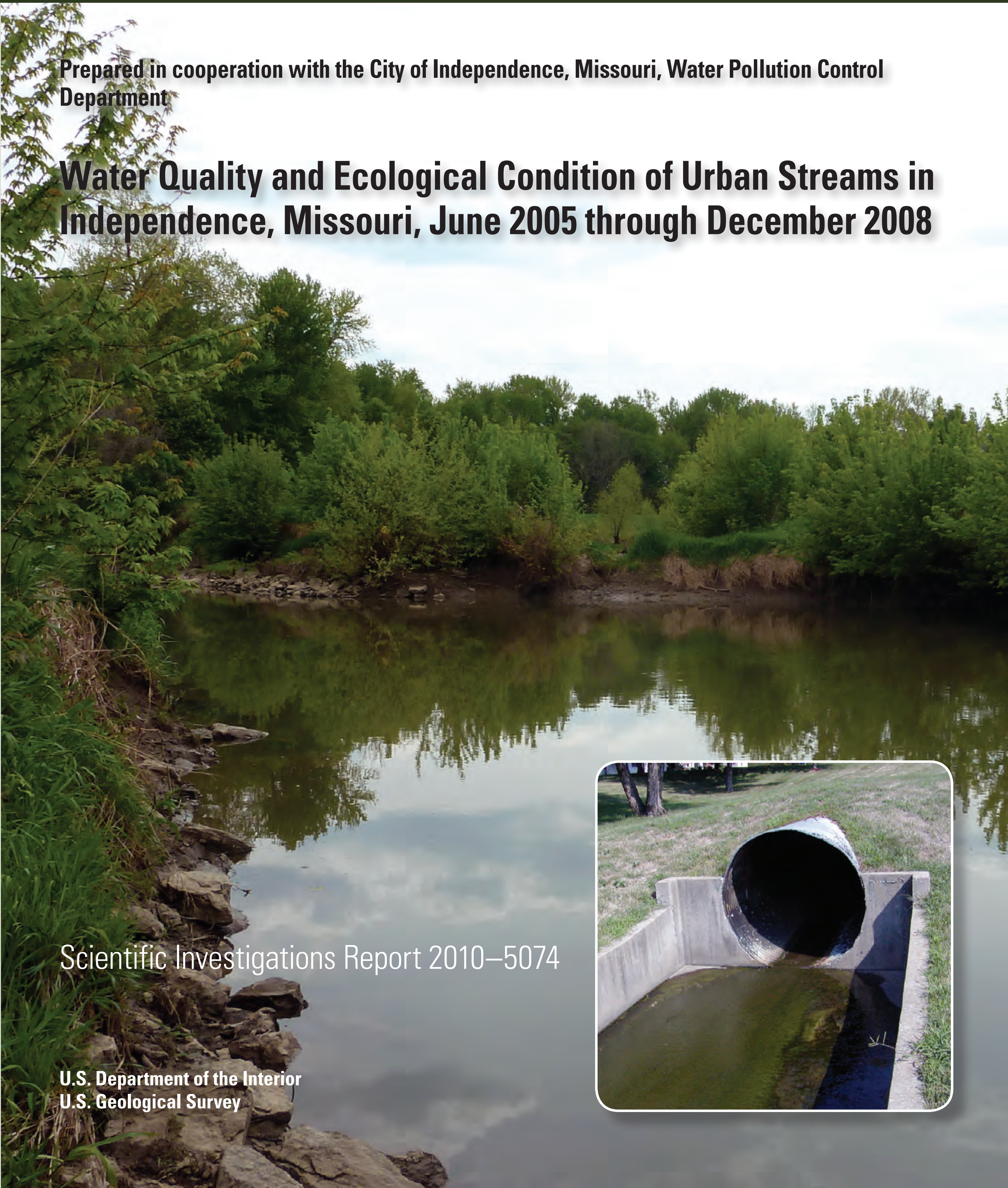

Prepared in cooperation with the City of Independence, Missouri, Water Pollution Control Department

Water Quality and Ecological Condition of Urban Streams in Independence, Missouri, June 2005 through December 2008

Scientific Investigations Report 2010–5074

U.S. Department of the Interior
U.S. Geological Survey

Front cover. Little Blue River near Lake City, Missouri (site 6) Photograph by Eric D. Christensen, U.S. Geological Survey, April 2010. Inset: Dry weather screening sample site, culvert within Crackerneck Creek Basin along MO-291 Highway, Independence, Missouri. Photograph by Richard D. Norman, U.S. Geological Survey, August 2006.

Back cover. Upper photograph: Flooding at the Little Blue River near Lake City, Missouri (site 6), looking upstream. Photograph by Shelley L. Niesen, U.S. Geological Survey, June 2010. Middle photograph: Little Blue River at 39th Street (site 3). Photograph by Shelley L. Niesen, U.S. Geological Survey, October 2007. Lower photograph: Little Blue River near Lake City, Missouri (site 6), looking downstream. Photograph by Eric D. Christensen, U.S. Geological Survey, June 2009.

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KEN SALAZAR, Secretary

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Marcia K. McNutt, Director

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Conversion Factors, Abbreviations, and Datums

Inch/Pound to SI

Multiply	By	To obtain
	Length	
inch (in.)	2.54	centimeter (cm)
mile (mi)	1.609	kilometer (km)
	Area	
square mile (mi^2)	2.590	square kilometer (km^2)
	Volume	
cubic foot (ft^3)	0.02832	cubic meter (m^3)
	Flow rate	
cubic foot per second (ft^3/s)	0.02832	cubic meter per second (m^3/s)

SI to Inch/Pound

Multiply	By	To obtain
	Length	
centimeter (cm)	0.3937	inch (in.)
meter (m)	3.281	foot (ft)
kilometer (km)	0.6214	mile (mi)
	Area	
square kilometer (km^2)	247.1	acre
square kilometer (km^2)	0.3861	square mile (mi^2)
	Volume	
liter (L)	0.2642	gallon (gal)
cubic meter (m^3)	264.2	gallon (gal)
cubic meter (m^3)	35.31	cubic foot (ft^3)
cubic meter (m^3)	0.0008107	acre-foot (acre-ft)
	Flow rate	
cubic meter per second (m^3/s)	35.31	cubic foot per second (ft^3/s)
	Mass	
gram (g)	0.03527	ounce, avoirdupois (oz)
kilogram (kg)	2.205	pound avoirdupois (lb)
megagram (Mg)	1.102	ton, short (2,000 lb)
milligram per second (mg/s)	0.000002	pound per second (lb/s)
gram per second (g/s)	0.002205	pound per second (lb/s)
kilogram per square kilometer (kg/km^2)	0.002854	tons per square mile (ton/mi^2)
kilogram per day per square kilometer ($kg/d/km^2$)	0.002854	tons per day per square mile ($ton/d/mi^2$)
megagram per day (Mg/d)	1.102	ton per day (ton/d)

Temperature in degrees Celsius (°C) may be converted to degrees Fahrenheit (°F) as follows:

$$°F=(1.8\times°C)+32$$

Temperature in degrees Fahrenheit (°F) may be converted to degrees Celsius (°C) as follows:

$$°C=(°F-32)/1.8$$

Vertical coordinate information is referenced to the North American Vertical Datum of 1988 (NAVD 88).

Horizontal coordinate information is referenced to the North American Datum of 1983 (NAD 83).

Specific conductance is given in microsiemens per centimeter at 25 degrees Celsius (µS/cm at 25°C).

Concentrations of chemical constituents in water are given either in milligrams per liter (mg/L) or micrograms per liter (µg/L).

Acronyms and Other Abbreviations

ABS	alkyl benzene sulfonate
AMLE	adjusted maximum likelihood estimation
ANOVA	analysis of variance
AQL	protection of aquatic life
BI	biotic index
BMP	best management practice
BOD_5	5-day biochemical oxygen demand
COD	chemical oxygen demand
col	colonies
CSO	combined sewer overflow
CWQM	continuous water-quality monitor
DNA	deoxyribonucleic acid
E. coli	*Escherichia coli*
EDL	estimated detection limit
EPA	United States Environmental Protection Agency
EPTR	Ephemeroptera-Plecoptera-Tricoptera richness
FBS	fully biologically supporting
GPS	global positioning system
IDAS	Invertebrate Data Analysis System
LAS	linear alkylate sulfonate
LRL	laboratory reporting level
LT-MDL	long-term method detection level
MDL	method detection limit
MDNR	Missouri Department of Natural Resources
MODOT	Missouri Department of Transportation
MPN	most probable number

MRL	minimum reporting level
MS4	municipal separate storm sewer system
MSCI	Missouri stream condition index
MST	microbial source tracking
N	nitrogen
NADP	National Atmospheric Deposition Program
NBS	non-biologically supporting
NH_3	ammonia
NO_2	nitrite
NO_3	nitrate
NPDES	National Pollution Discharge Elimination System
NURP	Nationwide Urban Runoff Program
NWIS	National Water Information System
NWQL	National Water Quality Laboratory
NWS	National Weather Service
OMC	common organic micro-constituent in whole water
P	phosphorus
PAH	polyaromatic hydrocarbon
PBS	partially biologically supporting
PVC	polyvinyl chloride
rep-PCR	repetitive extragenic palindromic polymerase chain reaction
R^2	coefficient of determination
RL	reporting level
RMSE	root mean square error
SCI	stream condition index
SDI	Shannon Diversity Index
SSO	storm sewer overflow
TTR	total taxa richness
USGS	United States Geological Survey
WY	water year, October 1 through September 30

Water Quality and Ecological Condition of Urban Streams in Independence, Missouri, June 2005 through December 2008

By Eric D. Christensen, Thomas E. Harris, and Shelley L. Niesen

Abstract

To identify the sources of selected constituents in urban streams and better understand processes affecting water quality and their effects on the ecological condition of urban streams and the Little Blue River in Independence, Missouri the U.S. Geological Survey in cooperation with the City of Independence Water Pollution Control Department initiated a study in June 2005 to characterize water quality and evaluate the ecological condition of streams within Independence. Base-flow and stormflow samples collected from five sites within Independence, from June 2005 to December 2008, were used to characterize the physical, chemical, and biologic effects of storm runoff on the water quality in Independence streams and the Little Blue River. The streams draining Independence—Rock Creek, Sugar Creek, Mill Creek, Fire Prairie Creek, and the Little Blue River—drain to the north and the Missouri River. Two small predominantly urban streams, Crackerneck Creek [12.9-square kilometer (km^2) basin] and Spring Branch Creek (25.4-km^2 basin), were monitored that enter into the Little Blue River between upstream and downstream monitoring sites. The Little Blue River above the upstream site is regulated by several reservoirs, but streamflow is largely uncontrolled. The Little Blue River Basin encompasses 585 km^2 with about 168 km^2 or 29 percent of the basin lying within the city limits of Independence. Water-quality samples also were collected for Rock Creek (24.1-km^2 basin) that drains the western part of Independence.

Data collection included streamflow, physical properties, dissolved oxygen, chloride, metals, nutrients, common organic micro-constituents, and fecal indicator bacteria. Benthic macroinvertebrate community surveys and habitat assessments were conducted to establish a baseline for evaluating the ecological condition and health of streams within Independence. Additional dry-weather screenings during base flow of all streams draining Independence were conducted to identify point-source discharges and other sources of potential contamination. Regression models were used to estimate continuous and annual flow-weighted concentrations, loadings, and yields for chloride, total nitrogen, total phosphorus, suspended sediment, and *Escherichia coli* bacteria densities.

Base-flow and stormflow water-quality samples were collected at five sites within Independence. Base-flow samples for Rock Creek and two tributary streams to the Little Blue River exceeded recommended U.S. Environmental Protection Agency standards for the protection of aquatic life for total nitrogen and total phosphorus in about 90 percent of samples, whereas samples collected at two Little Blue River sites exceeded both the total nitrogen and total phosphorus standards less often, about 30 percent of the time. Dry-weather screening identified a relatively small number (14.0 percent of all analyses) of potential point-source discharges for total chlorine, phenols, and anionic surfactants.

Stormflow had larger median measured concentrations of total common organic micro-constituents than base flow. The four categories of common organic micro-constituents with the most total detections in stormflow were pesticides (100 percent), polyaromatic hydrocarbons and combustion by-products (99 percent), plastics (93 percent), and stimulants (91 percent). Most detections of common organic micro-constituents were less than 2 micrograms per liter. Median instantaneous *Escherichia coli* densities for stormflow samples showed a 21 percent increase measured at the downstream site on the Little Blue River from the sampled upstream site. Using microbial source-tracking methods, less than 30 percent of *Escherichia coli* bacteria in samples were identified as having human sources.

Base-flow and stormflow data were used to develop regression equations with streamflow and continuous water-quality data to estimate daily concentrations, loads, and yields of various water-quality contaminants. Estimated chloride concentrations rarely exceeded the Missouri acute standard for the protection of aquatic life (about 1 percent) and at only one site, Spring Branch Creek. The chronic standard for chloride concentration at all sites was estimated to be exceeded between 2 and 30 percent of the time. Large specific conductance values measured in the Adair Creek Basin near Interstate 70 during dry-weather screening indicated potential chloride concentrations of about 1,100 milligrams per liter,

well above acute standards for the protection of aquatic life, but were not modeled. Estimated average daily total nitrogen and total phosphorus concentrations for the streams draining Independence were greater than U.S. Environmental Protection Agency recommended guidelines more than 85 percent of the time. Estimated concentrations for the Little Blue River sites exceeded the standard for total nitrogen more than 50 percent of the time and more than 80 percent of the time for total phosphorus. The estimated average daily sediment yield for the Little Blue River during the study period increased downstream, so that estimated annual suspended sediment loads were two to three times larger downstream with only about a 20 percent increase in total drainage area. Observed road, commercial, and residential construction activities in the lower portions of the stream basins draining Independence likely contributed to the larger suspended sediment loads. Estimated average daily *Escherichia coli* densities at both Little Blue River sites exceeded the Missouri standard 70 percent of the time.

Benthic macroinvertebrate samples collected in 2007 and 2008 found no sites, including reference sites, to be fully biologically supporting. Streams with a Stream Condition Index (SCI) of 16 to 20 are considered to be fully biologically supporting. The Little Blue River sites had an average SCI score of 12 and the streams draining Independence had an average SCI score of 10 and rated as partially biologically supporting. Habitat assessments were conducted in 2008. Scores for the Independence sites varied in a narrow range. The assessment factors having the most effect on lowering habitat scores were increased fine sediment deposition, channel alteration, poor bank stability, and loss or absence of bank and riparian vegetation.

Two streams draining Independence, Crackerneck Creek and Spring Branch Creek, contributed about 76 percent of the increase between sites on the Little Blue River in estimated chloride load, about 22 percent of the increase in total nitrogen load, and about 13 percent of the increase in total phosphorus load. Larger relative percentage contributions from the tributary streams occurred during lower flows. Estimated flow-weighted *Escherichia coli* densities also increased downstream. Contaminants mobilized through surface runoff to the municipal separate storm sewer system, and possibly sanitary sewer overflows, are more important in the smaller, more urbanized streams draining Independence than in the Little Blue River. Data collected for this study indicated that potential exists for decreasing concentrations, and consequently loads, of some contaminants to streams associated with suspended sediment in stormflow by the continuing implementation of best management practices to decrease sediment loads in streams.

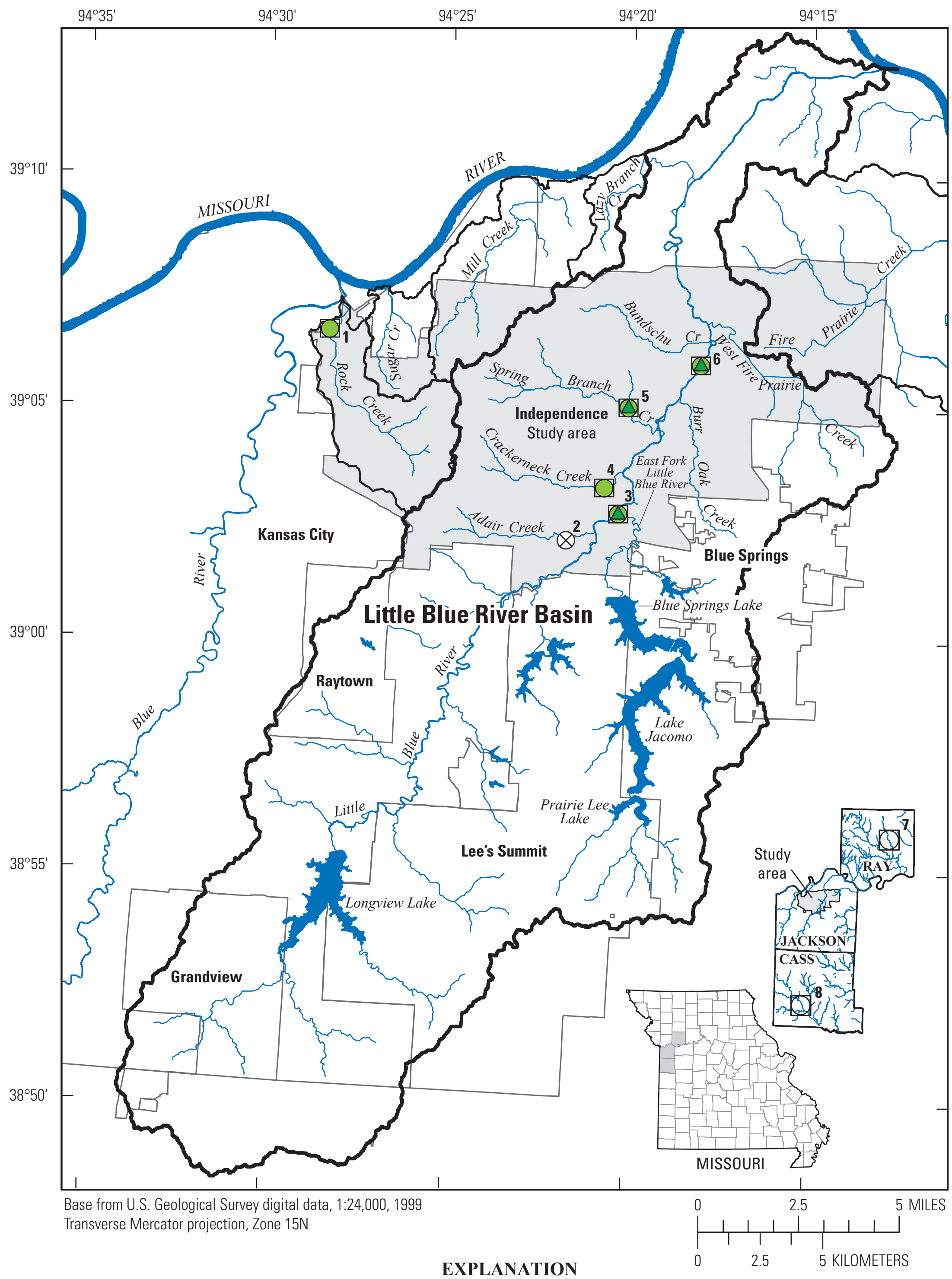
Introduction

In 1993, the U.S. Geological Survey (USGS), in cooperation with the City of Independence, Missouri completed a study characterizing the water quality of base flow in Independence streams and storm runoff from five basins draining the city (Schalk, 1993). The data collected for the study were used by Independence to establish baseline water-quality conditions for the National Pollution Discharge Elimination System (NPDES) permit application process for stormwater discharges to waters of the State of Missouri (U.S. Environmental Protection Agency, 1990). However, the effects of stormflow to the municipal separate storm sewer system (MS4) in Independence on the water quality and ecological condition of receiving streams, including the Little Blue River (fig. 1), were not assessed. Information about the source and character of contaminants detected in receiving streams was needed to meet the conditions of the MS4 permit for the city and to help design feasible and effective strategies by Independence for contaminant reductions and implementation of best management practices (BMPs).

Therefore, to identify the sources of selected constituents in urban streams and better understand processes affecting water quality and their effects on aquatic life on urban streams and the Little Blue River in Independence, the USGS in cooperation with the City of Independence, Missouri, Water Pollution Control Department initiated a study in June 2005 to characterize water quality and evaluate the ecological condition of streams within Independence. Sampling data from the monitoring program implemented for this study were used to fulfill the requirements of the MS4 permit for Independence, assess differences in the water quality of base flow and stormflow, and establish a water-quality baseline that could be used by Independence to measure the effectiveness of current (2010) and future BMPs to evaluate a stormwater management program for the city.

Purpose and Scope

This report presents the results of the first phase of a stream water-quality and ecological assessment of urban streams in Independence, Missouri. Continuous discharge (streamflow), physical properties, dissolved oxygen, chloride, metals, nutrients, suspended sediment, common organic micro-constituents (OMCs), and fecal indicator bacteria data for base-flow and stormflow samples are presented. These data were used to characterize contaminant sources, concentrations, loads, and yields for several basins and receiving streams within Independence and their contributions to the Little Blue River from June 2005 through December 2008. Regression models were used to estimate continuous and annual concentrations, loads, and yields of chloride, total nitrogen (N), total phosphorus (P), suspended sediment, and *Escherichia coli* (*E. coli*) bacteria. Microbial Source Tracking (MST), along with stream monitoring, dry-weather screening,



EXPLANATION

- 1 **Sampling site and number**—Green fill indicates streamflow and water-quality sampling site (table 1)
- 5 **Sampling site and number with continuous water-quality**
- 7 **Biologic sampling site and number**
- 2 **Sampling site and number with continuous water-quality monitor installed October 2008**

Figure 1. The Little Blue River Basin, sampling sites, study area location, and political boundaries, for Independence, Missouri, and surrounding cities.

benthic macroinvertebrate community surveys, and habitat assessments, were used in this study to identify and characterize contaminant sources and assess the ecological condition of streams in Independence. Measurements and estimates of constituent concentrations and fecal indicator bacteria densities indicate that there is potential for decreasing loads and concentrations of some constituents to streams, in particular nutrients, bacteria, and turbidity, associated with suspended sediment in stormflow by the continued implementation of BMP to decrease sediment loads to streams.

Description of Study Area

Independence, Missouri (fig. 1) is located in Jackson County, on the eastern side of the Kansas City metropolitan area. The study area is bounded by the city limits of Independence (fig. 2) and includes an area of 203 square kilometers (km^2). The population of Independence in 2007 was 110,704 (U.S. Census Bureau, 2008a) yielding a population density of about 540 people per square kilometer. The land use is a mix of developed (residential, commercial, industrial) and agricultural (fig. 3). The western one-half of the city is mostly urbanized with new, largely residential, construction occurring to the east on vacant and agricultural zoned land. In 2006, 50,247 housing units were in the city with 3,818 new units built from 2000 to 2006 (U.S. Census Bureau, 2008b).

The following basins drain most of Independence: Rock Creek, Sugar Creek, Mill Creek, Fire Prairie Creek, and the Little Blue River including its tributary streams; Adair Creek, East Fork Little Blue River, Crackerneck Creek, Spring Branch Creek, Burr Oak Creek, Bundschu Creek and West Fire Prairie Creek (fig. 2). No wastewater treatment facilities currently (2010) discharge to streams in the Little Blue River Basin, nor were any substantial effects from industrial discharges detected in samples during this study.

Five continuous streamflow-gaging stations (hereinafter referred to as streamgages) were the focus of this study (table 1; fig. 2): Rock Creek at Kentucky Road, USGS streamgage 06893620 (site 1); two sites on the Little Blue River, upstream at 39th Street, streamgage 06893910 (site 3), and downstream near Lake City, streamgage 06894000 (site 6); Crackerneck Creek at Selsa Road, streamgage 06893940 (site 4); and Spring Branch Creek at 78 Highway, streamgage 06893970 (site 5). Data collected for Adair Creek, streamgage 06893830 (site 2), installed in October 2008, are not included in this report. Two reference sites located outside of the study area (table 1; fig. 1); East Fork Crooked River near Richmond, streamgage 06895090 (site 7), and the South Grand River below Freeman, streamgage 06921582 (site 8), were selected and used as control sites for habitat assessment and benthic macroinvertebrate sampling. Sites 7 and 8 were selected as reference sites because they are representative of the ecoregions in which they and Independence are located and are nonurban streams that have had minimal human disturbance. Additional sites were identified during dry-weather screening and sampled.

Ecoregions and Climate

Independence straddles two of Missouri's major ecological sections, the Central Dissected Till Plains Section in the northern and western parts of the city and the Osage Plains Section to the south and east. These sections are characterized by shallow to deep loess soils overlying Pennsylvanian-age limestone, shale, and sandstone bedrock. These sections are further classified into subsections and land-type associations. In the northern part of the city the land-type association is classified as Missouri River Loess Woodland/Forest Breaks of the Loess Hills Subsection with steep slopes and drainages. The southeastern parts of Independence are in the Jackson County Prairie/Woodland Scarped Plain land-type association of the Scarped Osage Plains Subsection (Nigh and Schroeder, 2002). Historically, the natural vegetation consisted of a mosaic of oak woodlands and little bluestem-sideoats grama prairie, big bluestem-Indian grass prairie, and cord grass wet prairie. Agricultural uses in non-urban areas of the city include pasture and cropland with corn, soybeans, and other feed grains as main crops (Omernik, 1987; Chapman and others, 2001; Nigh and Schroeder, 2002).

The climate of Independence is classified as humid continental and is included within the Missouri Northwest Prairie climatic division (National Climatic Data Center, 2009). This climate is characterized by large seasonal temperature ranges and variable weather patterns. The 30-year (1979 through 2008) average annual temperature for the study area is 12.4 °C (degrees Celsius) and ranges from a average monthly low temperature of -1.9 °C for January to an average monthly high temperature of 25.0 °C for July [calculated from data reported at National Weather Service (NWS) Cooperative Stations 234158 (January 1979 through September 1989) and 234154 (January1990 through December 2008) located in Independence (fig. 2) or in the case of missing data, data from Kansas City Downtown Airport (MKC) and Kansas City International Airport (MCI) Cooperative Stations 234359 and 234154 were used]. Extreme temperatures in Independence for the 30-year period ranged from -26.7 °C in January 1982 to 42.8 °C in August 1984 (National Climatic Data Center, 1979–2008).

The 30-year average annual precipitation (liquid precipitation plus melted snow) is 109.0 centimeters (cm) with about 67 percent of the precipitation occurring during the growing season (April through September). The winter months (November through February) are relatively dry receiving about 18 percent of the precipitation. The 24-hour 2-year recurrence interval rainfall is 8.3 cm within the Northwest Prairie climatic division (Huff and Angel, 1992). Monthly average temperature and precipitation for the study period are shown in figure 4 with the 30-year monthly averages.

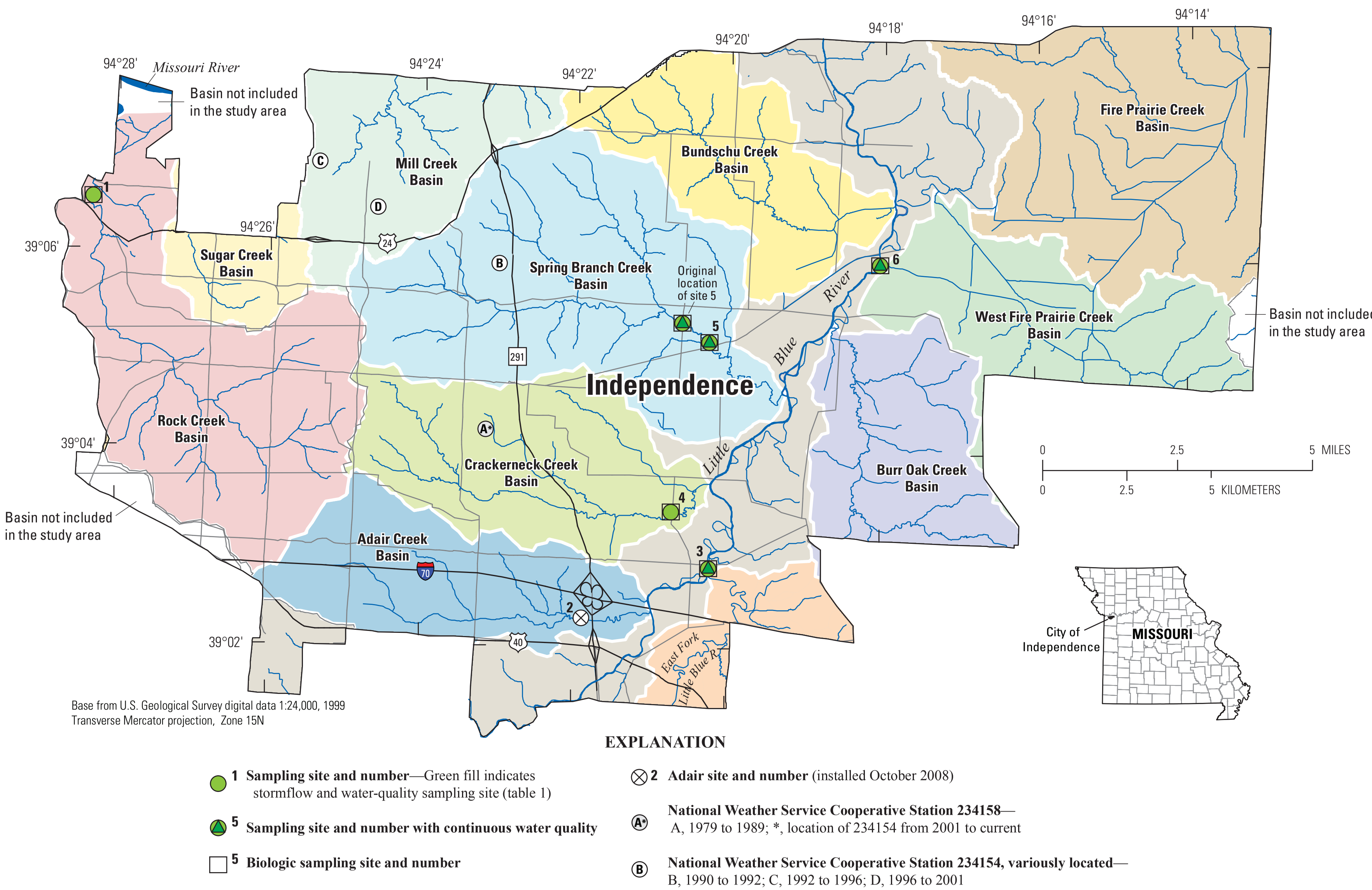
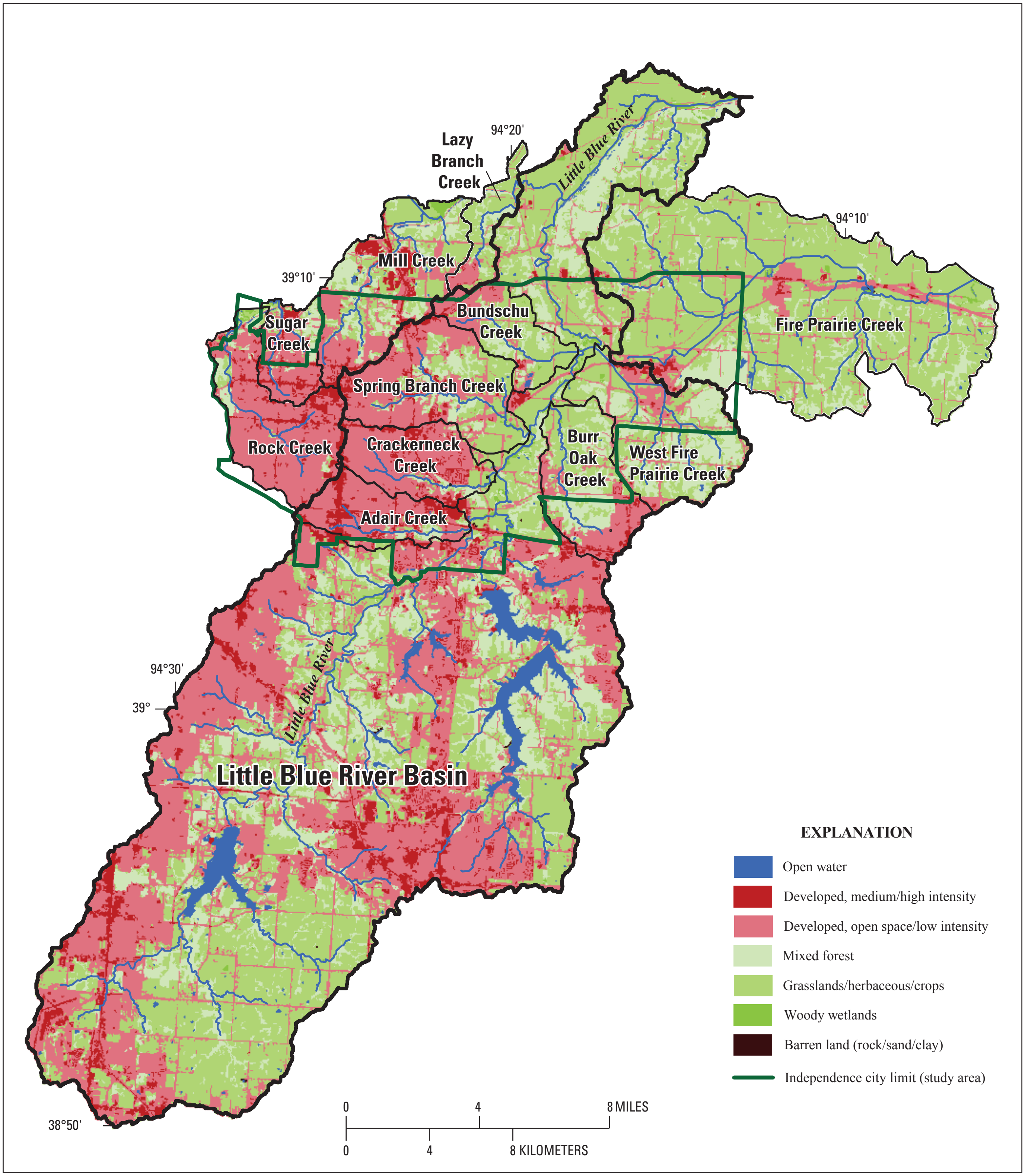


Figure 2. The study area in the City of Independence, Missouri, basin boundaries, and sampling sites.



Base from U.S. Geological Survey digital data 1:24,000, 2000
Universal Transverse Mercator projection
Zone 15N

Land use modified from U.S. Geological Survey National Land Cover Database (2001)

Figure 3. Land use/land cover in the Little Blue River Basin and adjacent basins within Independence, Missouri.

Table 1. Locations of sampled sites in Independence, Missouri, and biologic sampling reference sites and type of hydrologic, water quality, and ecologic data collected, June 2005 through December 2008.

[ID, identification number; ddmmss, degrees/minutes/seconds; km^2, square kilometers; mi^2, square miles; QC, continuous streamflow; PCP, precipitation; BQW, base-flow water quality; SQW, stormflow water quality with automatic samplers; CWQM, continuous water-quality monitor; IQW, benthic macroinvertebrates; HAB, habitat assessment; DWS, dry-weather screening; NA, not applicable; --, not sampled; X, sampled]

Site number (fig. 1)	Station name or basin	Station ID	Latitude (ddmmss)	Longitude (dddmmss)	Drainage area[1] (km^2)	Drain-age area[1] (mi^2)	Regulated drainage area[2] (percent)	QC	PCP	BQW	SQW	CWQM	IQW	HAB	DWS
1	Rock Creek at Kentucky Road in Independence, Mo.	06893620	390643	0942820	24.1	9.3	--	X	X	X	X	--	X	X	X
NA	Sugar Creek	NA	NA	NA	10.9	4.2	--	--	--	--	--	--	--	--	X
NA	Mill Creek	NA	NA	NA	28.2	10.9	--	--	--	--	--	--	--	--	X
2	Adair Creek	06893830	390216	0942148	12.4	4.8	--	--	--	--	--	--	--	--	X
3	Little Blue River at 39th Street in Independence, Mo.	06893910	390250	0942015	409	158	52.7	X	X	X	X	X	X	X	X
4	Crackerneck Creek at Selsa Road in Independence, Mo.[3]	06893940	390322	0942041	12.9	5.0	--	X	X	X	X	--	X	--	X
5	Spring Branch Creek at 78 Highway in Independence, Mo.[4]	06893970	390518	0942036	25.4	9.8	--	X	X	X	X	X	X	X	X
6	Little Blue River near Lake City, Mo.	06894000	390602	0941801	490	189	44	X	X	X	X	X	X	X	X
NA	Burr Oak Creek	NA	NA	NA	21.5	8.3	--	--	--	--	--	--	--	--	X
NA	Bundschu Creek	NA	NA	NA	11.9	4.6	--	--	--	--	--	--	--	--	X
7	East Fork Crooked River near Richmond, Mo.	06895090	392222	0945432	249	96	--	--	--	--	--	--	X	X	--
8	South Grand River below Freeman, Mo.	06921582	383520	0942630	388	150	--	--	--	--	--	--	X	X	--

[1]Drainage areas for sites with Station IDs are for the area upstream from the streamgage and sampling location.

[2]Percentage of total basin area at streamgage located upstream from reservoir outflows.

[3] Streamgage discontinued October 2008.

[4]Spring Branch streamgage moved downstream to Missouri State Highway 78 bridge on August 15, 2007, due to sedimentation at the site on Holke Road. Previous basin area was 24.1 km^2/9.3 mi^2.

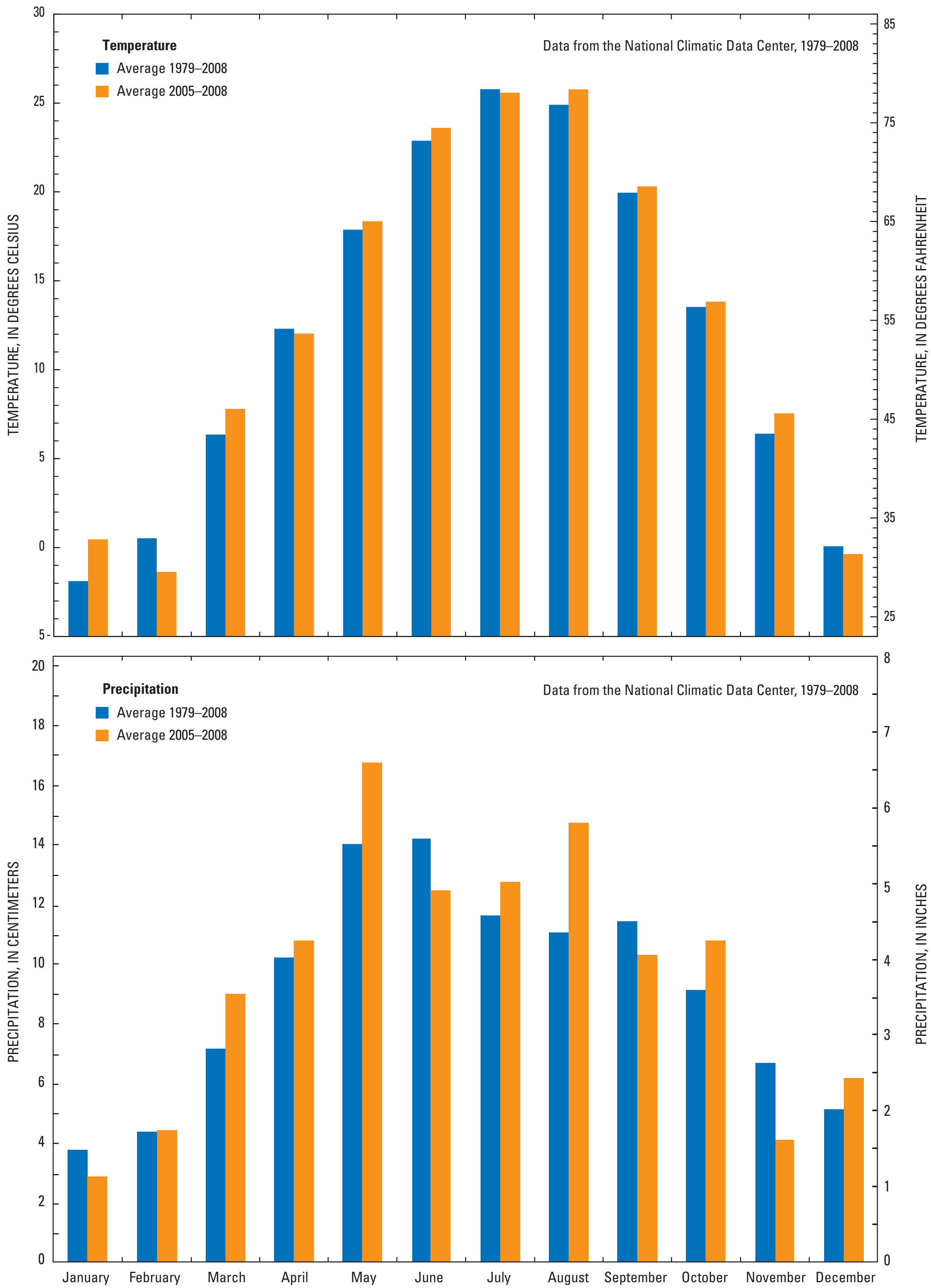


Figure 4. Monthly average temperatures and precipitation measured and recorded at Independence, Missouri, for July 2005 through December 2008 compared to the 30-year data from 1979 through 2008.

Hydrology

The streams draining Independence—Rock Creek, Sugar Creek, Mill Creek, Fire Prairie Creek, and the Little Blue River—drain north to the Missouri River. The Little Blue River and its tributaries (fig. 2) drain about two-thirds of the city. The Little Blue River Basin encompasses 585 km^2 with about 168 km^2 or 29 percent of the basin lying within the city limits of Independence (fig. 1).

Streamflow for the Little Blue River is affected by reservoirs; Longview Lake on the main stem of the Little Blue River, and Prairie Lee Lake, Lake Jacomo, and Blue Springs Lake on the East Fork Little Blue River (fig. 1). The dam for Longview Lake was completed in 1985 (U.S. Army Corps of Engineers, no date). Dams on the East Fork of the Little Blue River were constructed earlier. Construction on the dam for Prairie Lee Lake, the furthest upstream lake, began in 1936. The dam for Blue Springs Lake, the last constructed and the furthest downstream lake, was completed in 1986 and the lake filled in 1987 (Heimann, 1995; Rouse, 2004). These reservoirs regulate runoff from about one-half of the drainage area in the Little Blue River Basin (table 1).

The Little Blue River is mostly channelized within the city limits of Independence and is classified by Missouri as a Class P (perennial) stream suitable for whole-body contact and secondary contact recreation (Missouri Department of Natural Resources, 2005–2009). Other streams classified for whole-body contact within Independence are the East Fork Little Blue River and Fire Prairie Creek (Class P) and Burr Oak Creek (Class C, streams with perennial pools that may cease flow during periods of drought). Other streams in Independence are unclassified.

Previous Investigations

Streamflow measurements began in 1948 on the Little Blue River (site 6; fig. 2) and have been maintained continuously to the present (2010; U.S. Geological Survey, 2009b). Various other streamgages have been operated in the city from time to time including those that were part of the Nationwide Urban Runoff Program (NURP) study (U.S. Environmental Protection Agency, 1983) and by the USGS in 1992 and 1993 (Schalk, 1993).

The NURP was a research project conducted by the U.S. Environmental Protection Agency (EPA) between 1979 and 1983 and was the first comprehensive study of urban stormwater pollution across the United States. The Rock Creek Basin in Independence was included in the Kansas City Area NURP that was one of 28 urban areas that took part in the national program. One NURP site (RS3) was located at the same site as this study's Rock Creek sampling site (site 1; fig. 2) (Mid-America Regional Council and F.X. Browne Associates, Inc., 1983). The primary conclusion of the NURP study was that much pollution was coming from urban runoff and that, if action was not taken, the goals of the Clean Water Act would not be met (U.S. Environmental Protection Agency, 1983). Results from the NURP study were the foundation for the NPDES permit program.

In 1992 and 1993, the USGS, in cooperation with Independence, completed a study of the water quality of base flow in Independence streams and stormflow from five basins within the city (Schalk, 1993). Base-flow water quality was evaluated and samples were collected during three storms. A total of 193 base-flow samples were screened for four constituents indicative of point-source discharges. Chlorine concentrations were detected in 23 percent of the samples. A single detection of total detergents in base flow was determined, but no detections of copper or total phenols with method detection limits (MDL) that were larger than in the study described in this report. Stormflow samples were analyzed for physical properties, nutrients, trace elements, pesticides, volatile and semi-volatile organic compounds, and fecal indicator bacteria. However, no data interpretation was done.

OMCs are useful indicators of anthropomorphically affected point and non-point discharges to urban streams (Kolpin and others, 2002; Zaugg and others, 2006). These compounds have been used in studies of wastewater and wastewater treatment plant discharges to environmental waters including in the adjacent Blue River Basin in Missouri and Kansas (Wilkison and others, 2002, 2006, 2009; Lee and others, 2005). OMCs generally have been referred to as wastewater indicator compounds or wastewater contaminants in the literature (Kolpin and others, 2002; Wilkison and others, 2002, 2006, 2009; Zaugg and others, 2002, 2006; Lee and others, 2004; Lee and others, 2005). However, although these compounds are indicative of wastewater discharges, they also can have other sources including, but not limited to, runoff from roads, parking lots, lawns, golf courses, agricultural fields and gardens, organic plant matter, garbage and construction materials, landfills, groundwater, and atmospheric deposition (Adolphson and others, 2001; Peck and Hornbuckle, 2006; Ternes and Joss, 2006; Senior and Cinotto, 2007; Musolff and others, 2009). Many of these compounds have become ubiquitous in the environment (Kolpin and others, 2002), especially within and downstream from urban areas (Kolpin and others, 2002, 2004; Wilkison and others, 2006, 2009). For these reasons these compounds will be referred to in this report by a more generic term, common organic micro-constituents—OMCs—to avoid potential mis-attribution to the likely source of these compounds.

Methods

Streamflow, precipitation, water-quality, biologic, and ecological data were collected from June 2005 through December 2008 to characterize water quality and the ecological condition of streams in Independence. Along with the existing streamgage for the Little Blue River (site 6), four additional USGS streamgages were installed for this study, Rock Creek, Little Blue River at 39th Street, Crackerneck Creek, and Spring Branch Creek (sites 1, 3, 4, and 5; table 1; fig. 2). The streamgage at site 5 was moved a short distance downstream in August 2007 and the streamgage at site 4 was discontinued in October 2008 (fig. 2). Stream sampling sites were selected to be representative of the streams draining the developed areas of Independence that receive discharge from the MS4 and the city's contribution to the water quality of the Little Blue River. By definition, an MS4 is a system of conveyances that include man-made channels, pipes, tunnels, and storm drains, as well as surface streets, catch basins, curbs, gutters, and ditches that discharge into waters of the United States (Electronic Code of Federal Regulations, 2009). Data from each site included streamflow, physical properties, dissolved oxygen, chloride, metals, nutrients, suspended sediment, OMCs, and fecal indicator bacteria. Screening at low flow for point-source discharges and stream degradation such as garbage dumping was conducted. Evaluations of the ecological condition and health of streams also were done, including benthic macroinvertebrate community surveys and habitat assessment.

Sample Collection and Procedures

Continuous streamflow (discharge) data were collected at four sampling sites (sites 1, 3, 5, and 6) from July 2005 through December 2008 and at one sampling site (site 4) from July 2005 through October 2008 (table 1). Water-surface elevation (stage) data were measured and recorded at 15-minute intervals and used in discharge record computation at five sites using non-contact radar stage sensors for the two Little Blue River sites (sites 3 and 6) or pressure transducers on the smaller streams (sites 1, 4, and 5). Stage data also were measured at 5-minute intervals to capture the 'flashy' nature of the smaller streams and were used to program automatic samplers for storm sampling, but were not used in discharge record computation. The stage-discharge relation was determined and maintained by making streamflow measurements by USGS personnel at each site using USGS standard methods (Rantz and others, 1982; U.S. Geological Survey, 2004, 2007; Oberg and others, 2005; Mueller and Wagner, 2009).

Precipitation data were collected using unheated tipping-bucket rain gages co-located at each streamgage. The rain gages were regularly checked and cleaned as necessary. The rain gages were calibrated annually to accurately measure each 0.025 cm of precipitation and the cumulative total recorded every 15 minutes. Because unheated tipping-bucket rain gages cannot accurately measure snowfall or other precipitation during freezing conditions, the tipping bucket data were supplemented with data from the nearest NWS cooperative station (234154, fig. 2) to calculate storm and monthly totals. Climatic data, including precipitation, have been recorded within Independence at a NWS cooperative station since 1973.

Continuous water-quality monitors (CWQM) were installed, operated, and maintained at three sites (sites 3, 5, and 6; table 1), according to procedures presented in Wagner and others (2006). The CWQMs were equipped with sensors to measure and record 15-minute data for turbidity, dissolved oxygen, pH, specific conductance, and water temperature (fig. 5). Real-time and daily data from July 2005 through December 2008 are available from the USGS National Water Information System (NWIS) at *http://waterdata.usgs.gov/mo/nwis/qw*. A CWQM was installed in October 2008 on Adair Creek (site 2, fig. 2). The 15-minute data for turbidity, dissolved oxygen, pH, specific conductance, and water temperature from October 2008 through December 2008 also are available from the USGS NWIS.

The CWQMs were installed in July 2005 inside 1-meter (m) lengths of 46-cm diameter corrugated metal pipe anchored to the stream bottom and positioned so that water velocity would be maintained around the sensors during low flow. The streamgage and CWQM at Spring Branch Creek (site 5) were relocated downstream (fig. 2) in August 2007 because of shallow water depths and increasing sediment deposition interfering with the turbidity and dissolved oxygen sensors at the original streamgage site. The new installation positioned the CWQM near the center of flow inside a 10.2-cm diameter polyvinyl chloride (PVC) conduit. The CWQM placement in the streams did not result in any consistent bias for any of the constituents measured at the sites as determined by cross-sectional measurements performed with an independent CWQM (Wagner and others, 2006). The CWQM sensors can be subject to biologic and sediment fouling and calibration drift while deployed. Therefore, the CWQMs were cleaned

Figure 5. Continuous water-quality monitor with (clockwise from upper left) turbidity, dissolved oxygen, pH, and combined specific conductance and water temperature sensors.

and calibrated regularly with an average of 17 days between site visits, but ranged from 2 to 49 days depending on stream conditions and sensor performance. All data collected by the CWQMs were corrected as needed based on knowledge of conditions at the individual stream sites, manufacturer's specifications, and methods presented by Wagner and others (2006) before being finalized.

Water-quality samples were collected as grab samples at the centroid of flow during base flow (defined as flow unaffected by runoff) and with automatic samplers during stormflow at five sites using standard USGS protocols (U.S. Geological Survey, variously dated). Base-flow samples were collected annually beginning in June 2006, with an additional sample collected in December 2006 to characterize base flow winter conditions. Twice annual sampling of base flow was initiated in the fourth quarter of 2008. Stormflow samples were collected quarterly beginning in June 2005 with an additional sample collected in the fourth quarter of 2006. One set of stormflow samples was collected manually at the sampling sites before the installation of automatic samplers in June 2005 and on one other occasion in October 2007 for site 3 when the automatic sampler failed to function.

Automatic samplers were programmed to collect flow-weighted composite samples once a predetermined stage threshold was exceeded. Individual samples at the programmed flow interval were pumped into a glass receiving vessel to create a single composite sample over the interval of the storm sampled. The sampler programs were adjusted for streamflow at each site for the expected volume of stormflow to collect samples over the rising limb, peak, and falling limb of the storm hydrograph. However, because of the difficulty of predicting the volume of stormflow for individual storms and the sometimes long duration of recessions, the rising limb for most composites was sampled more frequently than the falling limb. Stormwater sample concentrations, therefore, are likely biased high in comparison to concentrations for samples collected over the total duration of a storm. For storms at the Little Blue River sites 3 and 6, between about 10 and 80 percent of stormflow volumes were sampled with an average of about 38 percent. A greater average percentage was sampled upstream for the Little Blue River at site 3 (about 45 percent) because of smaller total stormflow volume than downstream at site 6 (about 32 percent). Smaller percentages are largely attributable to storms with recessions of long duration (sometimes days) on the larger stream. Sampling was terminated for storms producing runoff for long durations, generally within 24 hours from the start of sampling, to process the water already collected for analyses in a timely manner. One storm at site 3 was sampled during about 35 hours. For storm sampling at the other sites (sites 1, 4, and 5), between about 30 and 95 percent of stormflow volume was sampled with an average of about 69 percent. For long sampling events (greater than 6 hours), the sampling vessel was either placed on ice in the automatic sampler or the partial sample was removed and refrigerated and composited later with the remainder of the water collected for the storm. Details of the USGS sample collection procedures can be accessed on line at *http://pubs.water.usgs.gov/twri9A*.

Base-flow and stormflow water-quality samples were analyzed for physical properties, dissolved oxygen, chloride, metals (total aluminum, arsenic, cadmium, chromium, copper, lead, zinc, and dissolved mercury), nutrients (dissolved and total nitrogen and phosphorus species), suspended sediment, OMCs, and fecal indicator bacteria. One set of stormflow samples in October 2007 was analyzed for dissolved metals in addition to the total analyses to assess the bioavailability of metals in stormflow. Physical properties were either measured in stream at the time of sample collection for grab samples (base-flow samples) or in the laboratory for composite samples (most stormflow samples) or calculated from the CWQM data. Dissolved oxygen was either measured in stream at the time of sample collection or obtained from the CWQM data. Nutrients, chloride, metals, and OMCs in samples were analyzed at the USGS National Water Quality Laboratory (NWQL) in Lakewood, Colorado, using established USGS procedures (Fishman and Friedman, 1989; Fishman, 1993; Zaugg and others, 2002, 2006). Cyanide samples were analyzed at TestAmerica Laboratories, Incorporated, in Arvada, Colorado, using EPA approved methods (TestAmerica Laboratories, 2009). Suspended sediment concentration samples were analyzed at the USGS sediment laboratory in Rolla, Missouri according to methods presented in Guy (1969). Data for samples for 5-day biologic oxygen demand (BOD_5) and chemical oxygen demand (COD) that were analyzed at the Independence Rock Creek Wastewater Treatment Plant by city personnel are presented, but not interpreted in this report.

Dry-weather screening of selected streams in Independence was conducted annually beginning in 2006. Screening was conducted by walking a stream from the mouth of the stream upstream to the point where streamflow was no longer evident or where the city limits were reached. Any measureable inflow or tributary of the selected stream was sampled, except for clearly identifiable low volume [flow less than 0.01 cubic foot per second (ft^3/s)] or diffuse groundwater seeps. All inflows were identified visually (small stream, pipe, culvert, groundwater seep, or pond overflow) and global positioning system (GPS) locations were obtained. At each sampling point, streamflow was measured or estimated and pH, specific conductance, and water temperature were obtained with calibrated portable field meters according to established USGS methods (U.S. Geological Survey, variously dated). A total of 536 samples were collected during the dry-weather screening process. However, sometimes because of insufficient sample volumes, some constituents could not be analyzed. Water samples were collected for analysis of total chlorine, free and complexed copper (total dissolved copper), phenols, and anionic surfactants. Anionic surfactants, in particular alkyl benzene sulfonate (ABS) and linear alkylate sulfonate (LAS), are common constituents in household and industrial cleaners and detergents. Analyses were conducted by colorimetric methods using Hach Company reagents and DR/2400® portable spectrophotometer at the USGS laboratory in Lee's

Summit, Missouri. Two of the methods (total chlorine and phenols) are equivalent to EPA methods for reporting water or wastewater analyses (Hach Company, 2004). The total chlorine analysis method is equivalent to EPA method 330.5 and Standard Method 4500-Cl G (Eaton and Franson, 2005) and is considered an EPA-acceptable method for reporting total chlorine concentration (Hach Company, 2004). The phenols method is equivalent to EPA method 420.1 for wastewater (Hach Company, 2004; U.S. Environmental Protection Agency, 1978). The methods employed for analysis of total dissolved copper and anionic surfactants have no equivalent EPA methods (Hach Company, 2004). The method for analysis of total dissolved copper uses ampules containing a reagent that changes color in the presence of copper. In the anionic surfactants analysis, the anionic surfactants in the sample are complexed with a crystal violet dye and extracted from the sample into benzene, that is used as the analysis medium.

A limitation of the colorimetric methods used for dry-weather screening is that suspended sediment or other material (turbidity) and some dissolved constituents may interfere either with the color development in a sample or light transmission when reading the sample in the spectrophotometer. Turbidity in base-flow samples can be introduced by suspending material during the sample collection process and can include sediment and organic material, such as detritus or algae. Bias (positive or negative) or error in the sample readings may occur. Standard procedures for the methods used for analysis of dry-weather screening samples recommend pretreatment of samples to remove interfering constituents and turbidity (Hach Company, 2004). However, for the purposes of this study, the data were used as a screening procedure and a less rigorous approach was used. All dry-weather screening samples were collected as unfiltered samples and chemical pre-treatment of the samples was not used. Samples with visually observable turbidity were allowed to settle for about 2 minutes after being transferred to a sample cell or ampule for reading in the spectrophotometer. The results from samples that still showed measureable readings for constituent concentrations with the spectrophotometer, but had visual turbidity or did not show visual color development in the judgment of the analyst, were deleted. The results that were deleted as a result of possible interference accounted for a total of 0.6 percent of the total chlorine samples, 3.4 percent of the total dissolved copper samples, and 0.2 percent of the anionic surfactant samples. No results for phenols were deleted. Deleted results were not included in statistical analyses.

Samples for fecal indicator bacteria—fecal coliform, *Escherichia coli (E. coli)*, and total coliform—were analyzed at the USGS laboratory in Lee's Summit. Fecal coliform samples were analyzed according to established USGS procedures (U.S. Geological Survey, variously dated). *E. coli* were analyzed using IDEXX Quanti-Tray® kits that utilize a semi-automated quantification method based on the Standard Methods Most Probable Number model (IDEXX, 2009) similar to a multi-test-tube dilution model where varying quantities of sample are diluted to fixed volumes. With the IDEXX method, 97 wells or reservoirs are filled with diluted sample water then sealed and incubated for 24 hours at 37 °C. After incubation, the number of wells that have turned yellow and the number of wells that fluoresce under ultra-violet light are counted. The counts then are compared to probability tables that give the most probable number (MPN) for total coliform (yellow counts) and *E. coli* (fluorescent counts). The MPN method does not involve counting bacteria colonies. Instead, the MPN method corresponds to a probable number that would be counted in a specific water sample. The number is expressed as most probable number of colonies per 100 milliliters (MPN/100 mL). For example, referring to the IDEXX probability tables, if 15 small wells fluoresce and 10 large wells fluoresce, the MPN is 28. This value represents the likely number of colonies per 100 milliliters (col/100 mL) that would be counted if the plate method was used. For the purposes of this report, the MPN/100 mL is considered to be comparable to col/100 mL.

For *E. coli* MST analyses, one set of base-flow and two sets of stormflow samples were collected. Base-flow samples were collected directly from the stream as a grab sample using sterilized equipment. Stormflow samples for MST analysis were collected with an automatic sampler in the same manner as for other constituents as previously described. An aliquot from the stormflow sample was then withdrawn from a sterilized churn for the MST subsample. The MST samples were shipped as soon as practical, usually within 8 hours, for analysis at the University of Missouri Veterinary Pathology Laboratory in Columbia, Missouri (Dombek and others, 2000; Carson and others, 2001, 2003, 2005). Repetitive extragenic palindromic polymerase chain reaction (rep-PCR) was used to produce the isolate deoxyribonucleic acid (DNA) 'fingerprints' of samples and to confirm that isolates were verifiably strains of *E. coli* using geographic-specific, genotypic library-based methods (Carson and others, 2003). Benthic macroinvertebrate samples were collected and processed from the five study sites and two reference sites (table 1, fig. 1) according to methods for the collection of biologic data in wadeable streams developed for the Missouri Department of Natural Resources (MDNR; Rabeni and others, 1997; Sarver, 2003a). Macroinvertebrate samples were collected from coarse-grained (sand- to boulder-sized) riffle habitats or, where such habitat was lacking, from other habitats having the greatest potential abundance, usually snags and root mats. Six sub-samples from a variety of depth, stream velocity, and substrate environments were sampled at each site using a bottom aquatic kick net with a 500-micron mesh bag. Samples were composited in the field and processed and preserved in ethanol at the USGS laboratory in Lee's Summit. Preserved samples were then shipped to the USGS NWQL for enumeration and taxonomic identification according to USGS protocols (Moulton and others, 2000, 2002).

Habitat assessments were conducted according to methods developed by the MDNR (Sarver, 2003b). Visual observations of stream substrate, periphyton and macrophyte taxon presence and growth, turbidity and sediment deposition, bank stability and vegetative growth, and riparian corridor width were made at five locations along a predetermined stream reach that included the macroinvertebrate sampling sites for this study. Field measurements of water temperature, dissolved oxygen, and specific conductance also were recorded. Observations were scored according to Sarver (2003b) and the results recorded on a standard form.

Data Analysis

Water-quality and ecological data from sites included in this study (table 1) were analyzed for various factors that are indicative of or can affect stream health and contaminant loads in streams. Concentrations, loads, and yields for chloride, total N, and total P, suspended sediment, and *E. coli* density at the five sampling sites were subjected to nonparametric statistical analyses to identify differences, if any, among concentrations, loads, and yields of constituents from different basins and between the upstream and downstream Little Blue River sites. Nonparametric methods were used because water-quality data often are not normally distributed and frequently contain extreme or censored values, or both (Helsel and Hirsch, 2002).

The Kruskal-Wallis rank sum test was used to initially screen for differences between sites. If the Kruskal-Wallis test indicated a likelihood of significant differences between sites [p value less than (<) 0.05] a one-way analysis of variance (ANOVA) test was computed on the ranked data. A multiple comparison t-test on ranks using the Tukey method was then used to identify differences between individual sites (Helsel and Hirsch, 2002). Estimated concentrations were retained and used in calculations for the statistical tests along with all detections above the minimum reporting level (MRL) of the laboratory at which samples were analyzed. Generally, estimated concentrations are those detected constituent concentrations greater than zero reported between the MDL and MRL and do not imply any precision of the quantitative measurement. Similarly, for samples analyzed at the USGS NWQL, estimated concentrations are those that are reported between the long-term method detection level (LT-MDL) and the laboratory reporting level (LRL; Childress and others, 1999). A significance level, alpha (α), of 0.05 was used for all tests.

The power of a test (in this case one-way ANOVA) is the likelihood of finding a difference that exists between sample sets, as opposed to the likelihood of identifying a difference that does not exist. For this study the number of samples at each site collected for base flow [number of samples (n) = 5] and stormflow (n=15-20) is small so that the applied statistical tests lack power ($1-\beta < 0.80$, where β equals the false negative rate). Increasing sample size increases statistical power (Helsel and Hirsch, 2002). The computer program TIBCO Spotfire S+® version 8.1 (The Information Bus Company Software Inc., 2008) was used for all statistical analyses in this report.

Because of the large number (68) of OMCs analyzed in the samples, the compounds have been broadly divided into categories used by Wilkison and others (2006); antioxidant, detergent, disinfectant, fire retardant, flavoring or fragrance, polyaromatic hydrocarbon (PAH) or combustion by-products, pesticide, plastics, solvent, sterol or stanol, and stimulant (table 2). However, many OMCs have numerous uses and these categories are not considered to be definitive of the origin of the compounds detected.

Instantaneous loads of selected constituents and OMCs in base flow and stormflow at stream sites were calculated by multiplying the measured concentration of a constituent by the instantaneous streamflow at the time of sampling (or average streamflow for composite samples) and a constant to normalize units. Daily, monthly, and annual loads were estimated for selected constituents using LOADEST, a FORTRAN-based load estimator program (Runkel and others, 2004). LOADEST develops regression models for constituent loads using explanatory variables including functions of streamflow and time as well as user-specified variables such as seasonal periods and physical properties. For this study, the dependent variable was the log-transformed constituent load and the independent variables included one or more of the following: log-transformed streamflow, linear time, seasonal variables and turbidity or specific conductance. Three hydrological seasons determined from cyclical streamflow characteristics consistent with other local area studies (Rasmussen and others, 2008) were specified for use in the models; a high runoff spring and early summer season (March through July), a transitional late summer and fall season (August through October), and a low runoff winter season (November through February). The Adjusted Maximum Likelihood Estimation Method (AMLE) was selected as the statistical estimation method for all sites and constituents. The AMLE assumes a normal distribution of the model calibration errors and is the method of choice when the data have censored values (Runkel and others, 2004).

Continuous water-quality properties (turbidity, dissolved oxygen, pH, and specific conductance) were considered for inclusion as explanatory variables in models at the three sites equipped with CWQMs (table 1). Explanatory variables were only included in the regression models if there was a physical basis and when they improved the model fit. As an example, at all three sites the inclusion of specific conductance as an explanatory variable for chloride concentration improved model estimates. The estimated average daily chloride concentration at Spring Branch Creek (site 5) from two LOADEST models is shown in figure 6. The first model includes variables for streamflow and seasonality [root mean squared error (RMSE) = 0.68, coefficient of determination (R^2) = 0.93], whereas the second model has specific conductance added as an explanatory variable (RMSE = 0.48, R^2=0.96).

Modeled chloride concentrations were derived using a small number of environmental samples (n = 25) over a relatively long time (42 months). Few of the samples were collected during the winter months (fig. 6). Because of this, the duration of elevated estimated chloride concentrations during the winter season likely are overestimated in the first, streamflow derived, model when compared to the model using specific conductance as an explanatory variable. However,

Table 2. Categories of common organic micro-constituents detected in urban streams.

[PAH, polycyclic aromatic hydrocarbon; categories adapted from Zaugg and others, 2002; Lee and others, 2005; Wilkison and others, 2006]

Antioxidant	Detergent	Disinfectant	Fire retardant
5-Methyl-1H-benzotriazole	4-Cumylphenol	Phenol	Tributylphosphate
3-tert-Butyl-4-hydroxyanisole (BHA)	4-Nonylphenol	Tribromomethane	Tris (2-chloroethyl) phosphate
	4-n-Octylphenol	Triclosan	Tris (dichloroisopropyl) phosphate
	4-tert-octylphenol		
	Ethoxy-nonylphenol		
	Diethoxy-nonylphenol		
	Ethoxy-octylphenol		
	Diethoxy-octylphenol		
Flavoring or fragrance	**PAH or combustion by-product**	**Pesticide**	**Plastics**
3-Methyl-1H-indole (skatol)	1-Methylnaphthalene	1,4-Dichlorobenzene	Bis(2-ethylhexyl) phthalate
Acetophenone	2,6-Dimethylnaphthalene	3,4-Dichlorophenyl isocyanate	Bisphenol A
Acetyl hexamethyl tetrahydro naphthalene (AHTN)	2-Methylnaphthalene	9,10-Anthraquinone	Diethylphthalate
Camphor	Anthracene	Atrazine	Triethyl citrate
d-Limonene	Benzo[a]pyrene	Benzophenone	Triphenyl phosphate
Hexahydro-hexamethyl cyclopenta-benzopyran (HHCB)	Fluoranthene	Bromacil	Tris (2-butoxyethyl) phosphate
Indole	Naphthalene	Carbaryl	
Isoborneol	para-Cresol	Carbazole	
Isoquinoline	Phenanthrene	Chlorpyrifos	
Menthol	Pyrene	Diazinon	
Methylsalicylate		Dichlorvos	
		Metalaxyl	
		Metolachlor	
		N,N-diethyl-meta-toluamide (DEET)	
		Pentachlorophenol	
		Prometon	
Solvent	**Sterol or stanol**	**Stimulant**	
Isophorone	3-β-Coprostanol	Caffeine	
Isopropylbenzene (cumene)	Cholesterol	Cotinine	
Tetrachloroethene	beta-Sitosterol		
	beta-Stigmastanol		

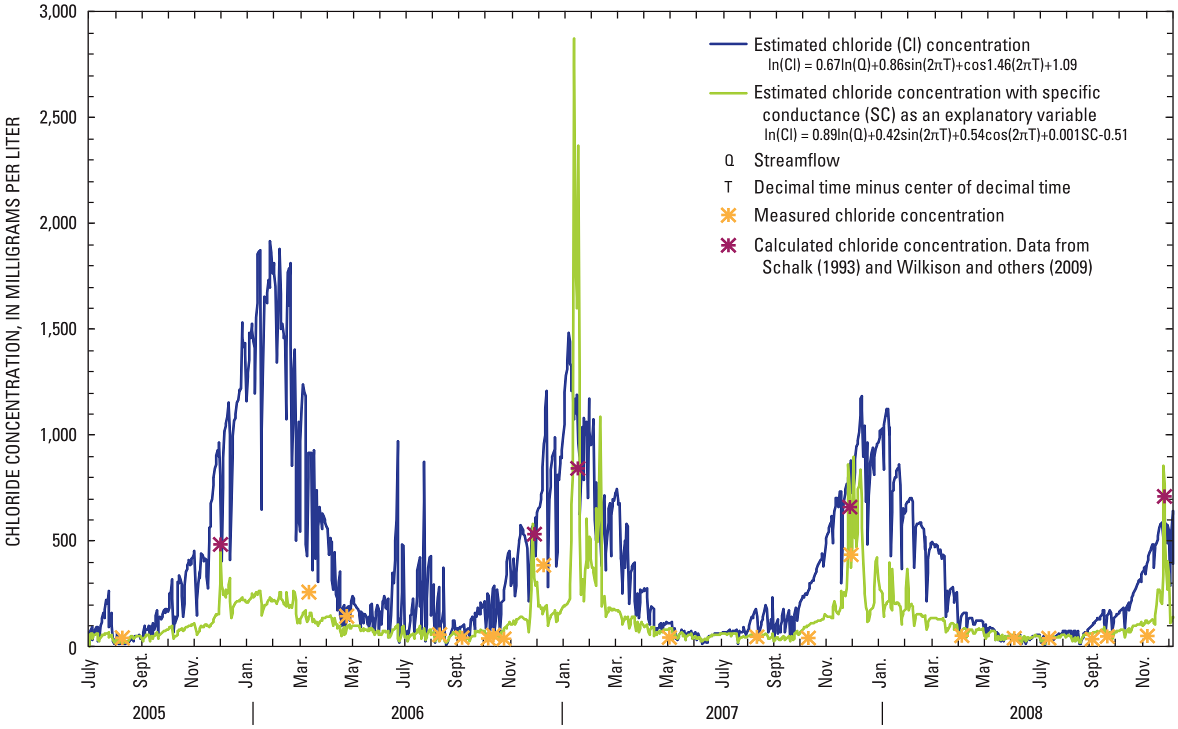


Figure 6. Average daily chloride concentration at Spring Branch Creek using regression models with and without specific conductance as an explanatory variable, July 2005 through December 2008.

the model with specific conductance tended to overestimate larger chloride concentrations because of a lack of measured chloride concentrations at the high end of the modeled specific conductance-chloride linear relation. The chloride concentrations are likely consistent in road salt, that is predominantly sodium chloride (NaCl). Therefore, calculated chloride concentrations were added to the model calibration data to improve model fit for large values of chloride at the high end. The calculated chloride concentrations were obtained by ordinary least squared regression from data in an earlier study in Independence (Schalk, 1993) and from an adjacent basin (Wilkison and others, 2009) that contain data with larger chloride concentrations and concurrent specific conductance measurements (fig. 7). As a consequence, the estimated annual loads for site 5 are 34 to 45 percent smaller as compared to loads from the first model without specific conductance as an explanatory variable. Similarly calculated data were used for the chloride models at sites 3 and 6 on the Little Blue River. Specific conductance data were not available for site 1 or site 4 so that modeled chloride loads at those sites are large.

In addition to chloride, loads and yields were estimated for total N, total P, suspended sediment, and *E. coli*. Total N is calculated by summing the calculated concentrations for ammonia (NH_3), nitrate (NO_3), nitrite (NO_2), and organic N. Flow-weighted concentrations were calculated from the estimated loads by dividing the average daily load by the average daily streamflow. Estimated yields were calculated by dividing the estimated constituent load by the drainage area of the site. Some annual summaries, average concentrations, loads, and yields are presented for water years (WY), October 1 through September 30, and are designated by the year in which it ends. Annual data in this report, unless specified for WY, are for the standard calendar year, January 1 through December 31.

Duration or frequency of exceedance curves are used to compare daily values for streamflow, physical properties, and dissolved oxygen at the three sites with CWQMs and for estimated daily concentrations of selected constituents at all sampling sites. Duration curves have commonly been used in water-resource studies to graphically illustrate the magnitude and frequency of streamflow and constituent concentrations (Searcy, 1959; Pettyjohn and Henning, 1979; Vogel and Fennessy, 1995) and more recently to characterize continuous water-quality data (Rasmussen and Ziegler, 2005; Rasmussen and others, 2005). Duration curves are constructed by plotting the ordered data for a given period in relation to the percentage of time a value is equaled or exceeded. Thus the smallest calculated or estimated values will have a frequency of exceedance of 100 percent and the largest values will have a frequency of exceedance approaching zero. The Weibull formula, $p = i/(n+1)$, where p is the plotting position, i is the value being plotted, and n is the total number of values, is used for the determination of plotting position of values for the duration curves in this report (Weibull, 1939; Helsel and Hirsch, 2002).

For the colorimetric analysis of dry-weather screening samples, the estimated detection limit (EDL) was determined by the manufacturer for each analysis method (Hach Company, 2004). A provisional MDL was determined by a

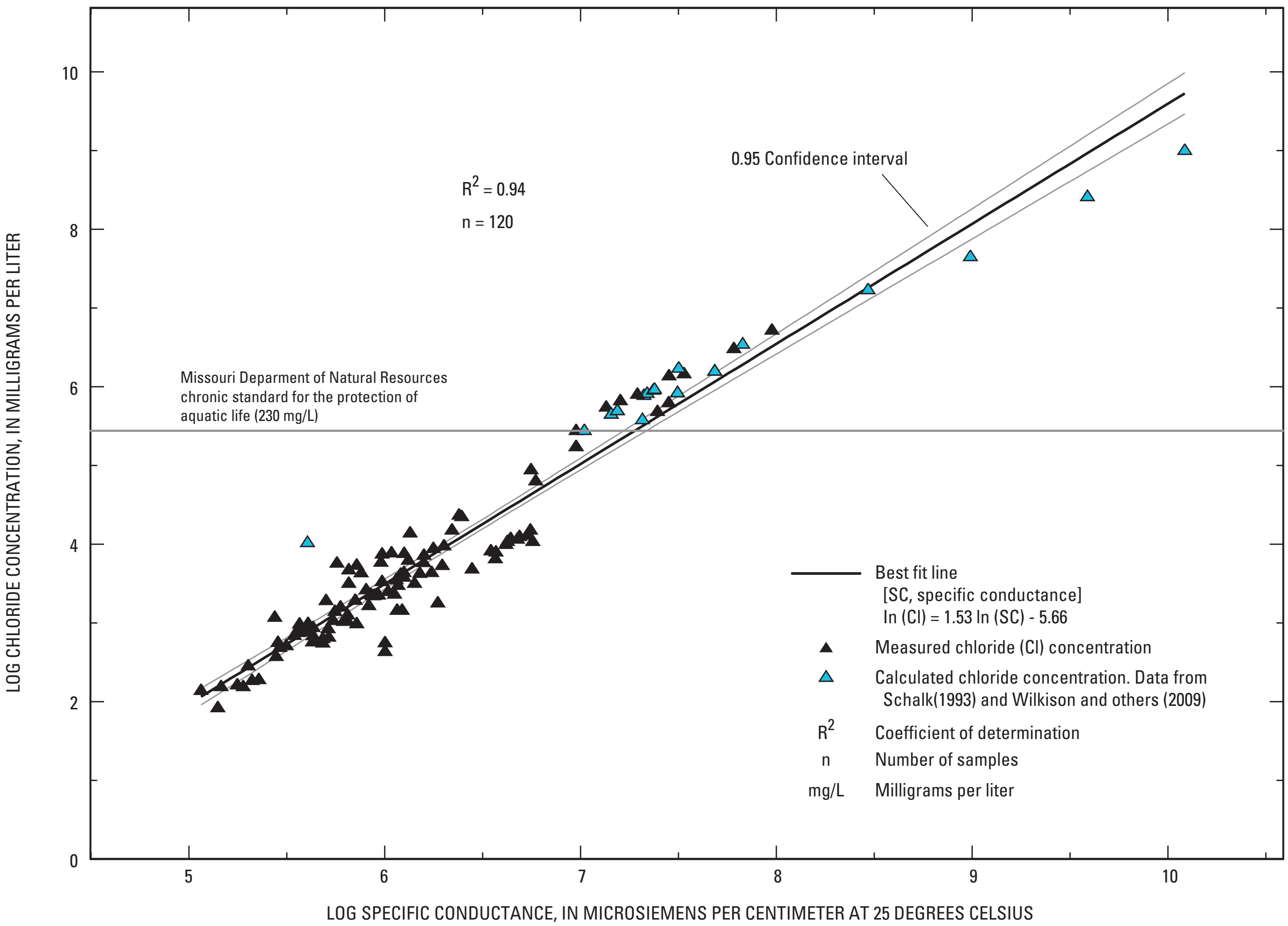


Figure 7. Relation between measured specific conductance and chloride concentrations in stream samples using measured and calculated chloride concentrations.

calculation of the average difference between the analysis results from pairs of environmental samples and replicates or duplicates. The average difference was then rounded to the nearest 0.05 or 0.005 milligram per liter (mg/L), depending on the analyte. The MDL represents the minimum concentration of a constituent that can be measured and reported with 99-percent confidence that the concentration is greater than zero (U.S. Environmental Protection Agency, 1997). The MDLs for the dry-weather screening analytes are therefore provisional, because a larger data set and analysis of spike samples (samples with a known concentration of analyte added to the sample) is required to determine an MDL with more rigor to the 99-percent confidence level. Some sample concentrations are between the EDL and the provisional MDL for a given method and are referred to as ‘M’ values, or concentrations that were detected but not quantified. However, numeric concentrations were specified for the ‘M’ values in the statistical analyses for each analyte.

Guidelines and standards were used to determine if the measured concentration of a dry-weather screening analyte would be considered for further investigation. Any discharge that had a measured concentration exceeding a guideline or standard was considered a potential point source of contamination. However, for most detections (65), a source could not be determined and were considered to be *de minimus* (minimal) and most likely attributable to episodic sources, such as lawn watering or car washing. For total chlorine, the State reportable/compliance level of 0.13 mg/L of total chlorine was used as a guideline (Missouri Department of Natural Resources, 2006). Concentrations of phenols were expressed as the equivalent concentration of the individual compound, phenol (Hach Company, 2004), so that the Missouri chronic standard for protection of aquatic life (AQL) of 0.100 mg/L for phenol was used (Missouri Department of Natural Resources, 2005–2009). The anionic surfactants standard of 0.028 mg/L was determined from the EPA freshwater standard for acute exposure for aquatic communities to nonylphenol, a nonionic surfactant (U.S. Environmental Protection Agency, 2006). Nonylphenol was the most commonly detected detergent (surfactant) in base-flow samples (data on file at the USGS Water Science Center office in Lee’s Summit). However, the anionic surfactant standard was used only as an arbitrary guideline for determining potentially reportable detections, because the measured concentration for all anionic surfactants would be expected to be higher than that for any one surfactant. Anionic surfactants often are present in environmental water samples in concentrations larger than nonionic surfactants, such as nonylphenol (Saitoh and others, 2000).

A standard was not determined for total dissolved copper because both Federal and State standards are for dissolved copper from filtered samples. The method used for total dissolved copper analysis included both free and complexed copper from unfiltered samples.

E. coli isolated from water samples for MST analysis were compared to a host-source library of *E. coli* DNA patterns from three hosts: dogs, geese, and humans. For MST analyses, a presumptive source of sampled bacteria is assigned through a statistical comparison of genetic markers obtained from environmental *E. coli* samples to genetic markers in the host-source library. The development of a host-source library specific to the Little Blue River Basin was beyond the scope of this study. A library of patterns developed for other studies in the local area (Wilkison and others, 2005, 2006) was used for the purposes of this study. In this report, data were classified as human, non-human (dog and geese), and unknown. Fingerprint patterns of *E. coli* from collected water samples were compared with patterns from the host-source library for similarity using BioNumerics software, version 3.0 (Applied Maths NV, 1998–2008), and assignment to a host group was made when sample patterns had an arbitrary 80 percent or greater similarity to those from a known host source in the library. The source was designated as unknown if the sample did not have at least an 80 percent similarity (A. C. Carson, University of Missouri Veterinary Pathology Laboratory, oral commun., 2009). The percentage of non-human, human, or unknown host source bacteria was calculated by multiplying the total number of *E. coli* in the sample by the number of patterns that were identified. The MST analysis results from the two Little Blue River sites (sites 3 and 6) were combined in this study to compare with the smaller Independence streams.

The Invertebrate Data Analysis System (IDAS) version 4 software was used for processing and computing metrics for abundance and diversity from benthic macroinvertebrate samples (T.F. Cuffney and R.A. Brightbill, written commun., 2009). Data from study sites (sites 1, 3, 4, 5, and 6) and reference sites (sites 7 and 8) were combined for the purpose of resolving taxonomic ambiguities. Taxa in most cases have been identified to the genus and species level. However, for those cases when the identification of a sample taxa has only been made at a higher taxonomic level (phylum, class, order, suborder, family, sub-family, or tribe), the abundance of the sample taxa (parent) was divided among the lower identified taxonomies (children) for the purposes of assigning pollution tolerance values. Assigning parents to children is equivalent to estimating data (T.F. Cuffney and R.A. Brightbill, written commun., 2009). Between 0 and 27 percent of the tolerance values for individual samples were assigned. However, by distributing the abundance of the parent among the children, tolerance values were able to be assigned to between about 97 to 100 percent of the taxa present in individual samples. A Stream Condition Index (SCI), similar to the Missouri Stream Condition Index (MSCI) developed by Sarver and others (2002), was calculated from four metric indices: Total Taxa Richness (TTR), Ephemeroptera-Plecoptera-Trichoptera Richness (EPTR), Biotic Index (BI), and the Shannon Diversity Index (SDI). The BI and SDI for this report were modified from the methods outlined by Sarver and others (2002). Additional taxa listings, other than the Missouri taxa listing, were used in calculating these indices. However, the calculated SCI and sample ratings are comparable to values for the MSCI.

The TTR metric is the total number of taxa identified for a sample and is a measure of the health of the macroinvertebrate community. Similarly, the EPTR metric is the sum of taxa from the pollution sensitive Ephemeroptera, Plecoptera, and Trichoptera taxonomic orders. Both the TTR and EPTR would be expected to increase with improving water quality and stream health. The BI quantifies the average tolerance of the macroinvertebrate community from a sample to organic pollution and increases with degrading stream health. The BI was calculated using tolerance values compiled for the MDNR (Sarver, 2005). If values for taxa could not be determined from the Missouri listing, then values were used from a compilation of average national tolerance values provided with IDAS (T.F. Cuffney and R.A. Brightbill, written commun., 2009).

The SDI is a measure of the variability within a macroinvertebrate community and increases with larger community diversity. The SDI was calculated using IDAS and converted to base *e* for the purpose of calculating an SCI comparable to the MSCI.

The SCI, comparable to the MSCI, was calculated by summing the normalized scores of the four metric indices and was used to determine the aquatic life support status of a stream and as a tool to assess the ecological condition of streams. Streams with an SCI of 16 to 20 are considered fully biologically supporting (FBS). Streams that have an SCI of 10 to 14 are considered partially supporting (PBS), and streams with an SCI of 4 to 8 are considered non-biologically supporting (NBS).

In September 2008, the physical habitat of four study sites (sites 1, 3, 5, and 6) and the two reference sites (sites 7 and 8) were assessed and scored using procedures developed by Sarver (2003b). A habitat assessment for Crackerneck Creek (site 4; table 1) was not conducted because of road and bridge construction at the site. A habitat assessment would not have been representative of conditions at the time of earlier macroinvertebrate sampling. The scores of 10 habitat attributes that affect aquatic life were summed to give an overall score. The higher the score out of a possible total score of 170 is indicative of habitat better able to support stream health.

Quality Control and Quality Assurance

About 10 percent of all water-quality samples collected during this study were quality-control samples. Quality-control samples are designed to test all aspects of the sample collection and analysis process (U.S. Geological Survey, variously dated). Quality-assurance procedures are intended to ensure the precision and accuracy of the water-quality data in this report.

Six different types of quality-control samples were used: field replicates and blanks; laboratory duplicates, blanks, and spikes; and accuracy checks. A field replicate is an additional sample collected at a site in a separate bottle from the original sample. Field replicates provide a measure of the variability introduced during sample collection and processing. A field blank is prepared on site using either deionized or organic-free water rather than environmental water and is collected and processed in the same manner as the environmental sample. Field blanks provide a check on whether sample collection and processing have introduced contamination. A laboratory duplicate is an additional analysis for a particular analyte performed on a single sample in the laboratory. Laboratory blanks, as with field blanks, are analyses performed using either deionized or organic free water rather than environmental water. Laboratory blank samples were analyzed to detect sample contamination during laboratory processing and analysis. Laboratory spikes are artificial samples created by adding a known quantity of a particular analyte to a sample and measuring the amount of recovery of that analyte. Accuracy checks involve creating an artificial standard of a known concentration, then running an analysis and determining the amount of recovery of the standard. Not all types of quality-control samples were used for all the categories of samples collected. Field and laboratory quality-control samples were collected and processed according to USGS standard water-quality sampling protocols (U.S. Geological Survey, variously dated).

Both field replicate samples and laboratory duplicate sample analyses were performed to determine the effect that variability in sample collection and processing procedures may have had on the precision of constituent concentrations (data on file at the USGS Water Science Center office in Lee's Summit). For most constituents (dry-weather screening samples are discussed separately), the differences in concentrations between replicate and duplicate pairs were small. In general, for all constituents, the largest relative percentage differences occurred at or near the minimum reporting level (MRL) for a constituent. The MRL is the lowest measured concentration of a constituent that may be reported reliably (Childress and others, 1999). The average relative percentage difference between pairs was less than 10 percent for all constituents except suspended sediment and *E. coli* samples. The average relative difference for suspended sediment pairs was 18.9 percent and for *E. coli* was 29.2 percent. The observed differences in suspended sediment pairs were most likely the result of temporal variability over the duration of sample collection (Kelly and others, 2001). These results for suspended sediment field replicates are not unusual (Miya N. Barr, U.S. Geological Survey, oral commun., 2009). The relatively large sampling error that was observed in field replicate samples for suspended sediment indicated that substantial temporal variability for suspended sediment can exist over relatively short time frames. Large differences in *E. coli* sample pairs have also been reported in other studies (Francy and Darner, 1998; Anderson and Rounds, 2003; Rasmussen, 2003; Brady, 2007). Rasmussen (2003) indicates that the large uncertainty in bacteria analyses may be because of the difficulty in obtaining representative sub-samples from highly turbid water. *E. coli* densities also can be expected to vary temporally in association with the re-suspension of bottom sediment and suspended sediment concentration in stream water (Stephenson and Rychert, 1982). In addition, Noble and others (2004) reported large with-in laboratory measured variability in *E. coli* densities using both standard (membrane filtration) and chromogenic substrate (IDEXX) methods.

Generally, the field and laboratory blank data concentrations support the conclusion that sample collection and processing procedures were not a source of bias. However, 10 detections (three not quantified) of OMCs were reported in four field blank samples (table 3, at the end of this report). The pesticides benzophenone and N,N-diethyl-meta-toluamide (DEET) were reported at small concentrations of 0.1 to 0.4 microgram per liter (µg/L) and were likely because of blank sample contamination. Insect repellants containing DEET are commonly used by USGS field technicians in Missouri. Although precautions were taken to avoid contaminating samples (not using repellants when collecting water-quality samples and hand washing), trace quantities may be present in field vehicles or on clothing. However, because three concentrations of DEET in blank samples were estimated, one not quantified, and the concentrations reported were low, sample cross contamination in the laboratory cannot be discounted (National Water Quality Laboratory, written commun., 2008). The other OMCs reported in blank samples; 4-nonylphenol, tributyl phosphate, tris(2-butoxyethyl) phosphate, and naphthalene, were either not quantified or were reported as estimated concentrations greater than zero, but less than the NWQL LRL (Childress and others, 1999; Zaugg and others, 2002). The NWQL LRL for a constituent is calculated as two times the LT-MDL (Childress and others, 1999).

For dry-weather screening samples, simple linear regression was used to compare the environmental samples with quality-control samples. Quality-control data for the environmental samples and the combined data from field replicates and laboratory duplicates are shown in figure 8. The total chlorine, phenols, and anionic surfactants replicate and duplicate analyses showed good correlation, with R^2 of 1.0, 0.94, and 0.98. However, both total chlorine and phenols had one sample pair with larger concentrations (outlier) than the other sample pairs. When these outlier pairs are removed from the regression data, total chlorine still exhibits good correlation (R^2=0.75), but phenols do not (R^2=0.19; fig. 8). Therefore, the reproducibility of phenol analyses at smaller concentrations, which is the case for most of the analyses for phenols, is less precise. The replicate and duplicate analyses for total dissolved copper had an R^2 of 0.07. However, the total dissolved copper concentrations were small, with most sample pairs less than the provisional MDL. In addition, the replicate and duplicate total dissolved copper samples did not compare well with environmental samples and spikes, and accuracy checks generally did not return recovery values within 10 percent of full recovery (data on file at the USGS Water Science Center

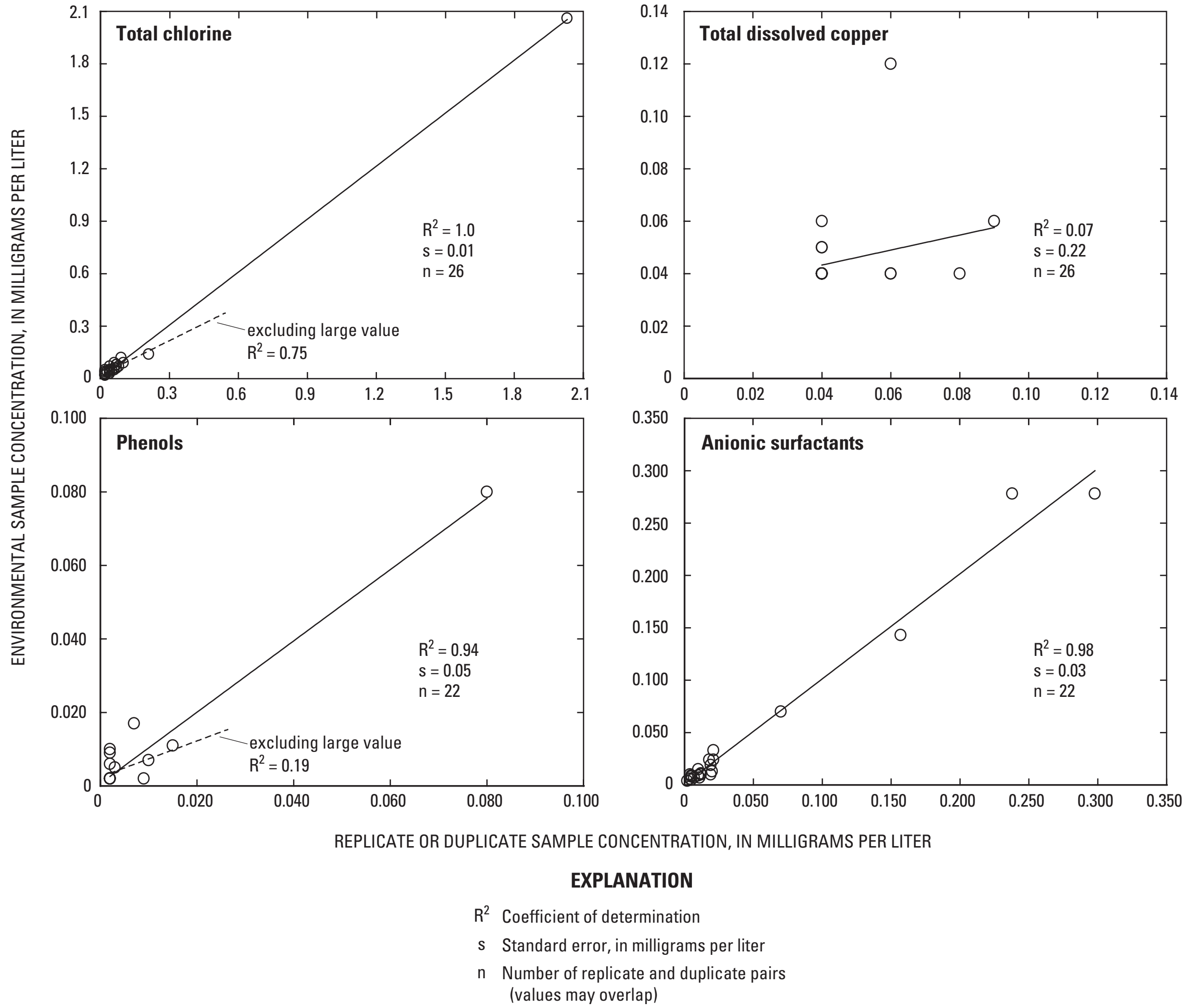


Figure 8. Quality-assurance data for dry-weather screening samples in field replicate or laboratory duplicate sample pairs.

office in Lee's Summit). Accuracy checks for each analyte (total chlorine, total dissolved copper, phenols, and anionic surfactants) were performed before and at the end of each annual sampling period and were performed by the same technicians who analyzed the environmental samples. All dry-weather screening results in this report are considered to be semi-quantitative.

Bacteria samples were analyzed using multiple dilutions to obtain an enumeration within the optimal range for bacteria density counts. When density counts were outside the optimal range, the densities were estimated using standard USGS procedures (U.S. Geological Survey, variously dated). The MST data were quality assured biannually by comparing *E. coli* samples originating from dogs, geese, and humans to the known samples in the geographic-specific genotype library. If the samples were correctly identified, then the library was considered to still be valid (A.C. Carson, oral commun., 2009).

The USGS NWQL uses additional quality-assurance procedures for water-quality samples designed to assess and quantify method performance, bias, variability, and instrument sensitivity and calibration. Laboratory quality-assurance procedures and methods are in Maloney (2005) accessible online at *http://nwql.usgs.gov/OFR-05-1263*. For benthic macroinvertebrate samples the NWQL uses a taxon-based approach to quality control (Grotheer and others, 2000; Moulton and others, 2000, 2002). All new taxa identified for a sample, in addition to a random 10 percent of all identifications, are reviewed for accuracy by a different taxonomist. Values reported as estimated by all laboratories doing analyses for this study are the result of deviations from the standard procedures of the laboratory (for example values less than the MRL or suspected interferences).

Water Quality

Water quality in the streams of Independence was determined by the measurement of physical properties, dissolved oxygen, chloride, metals, nutrients, suspended sediment, OMCs, and fecal indicator bacteria in base-flow and stormflow samples collected at five streamgages equipped with automatic samplers (sites 1, 3, 4, 5, 6; table 1). Results for fecal indicator bacteria sampling from both base-flow and stormflow samples are discussed together under a separate heading. Dry-weather screenings encompassing the basins of individual streams within the city limits of Independence (fig. 2) were conducted at low flow to identify any point-source discharges and are also discussed under a separate heading.

A variety of factors can affect water quality and constituent concentrations and loads in urban streams, including, but not limited to, the amount of impervious surface in the basin, type (combined or separate) and condition of the sanitary sewer system, land use (agricultural, residential, commercial, or industrial), use of lawn pesticides and herbicides, application of road salt, and handling of pet and animal waste. The primary components contributing to streamflow are groundwater discharge and surface runoff from precipitation and melt water. Industrial and municipal discharges also can have an effect, particularly at low flows. No wastewater treatment facilities currently (2010) discharge to streams in the Little Blue River Basin nor were any effects from industrial discharges detected during this study. However, sanitary sewer overflows (SSOs) have occurred during this study (U.S. Environmental Protection Agency, 2009), and were observed by USGS personnel on two occasions.

Not all effects on stream water quality are local in origin. Atmospheric contributions are an important source of various water-quality constituents (Clark and others, 2000; Carey and others, 2001; Alexander and others, 2008). Estimates of atmospheric deposition rates for selected constituents at five Midwestern sampling sites in Iowa, Kansas (two sites), Missouri, and Nebraska are presented in table 4 (at the end of this report) (National Atmospheric Deposition Program/National Trends Network, 2009)

Streamflow and Continuous Water-Quality Measurements

Daily values for streamflow were calculated for the five study sites (table 1) and ranged from no flow at Spring Branch Creek (site 5), during several days in June 2006, to 10,500 ft^3/s for the Little Blue River at site 6 in May 2007. The average of daily streamflow at all sites was less in WY 2006 than in WYs 2007 and 2008. For the streams draining Independence (sites 1, 4, and 5), WY 2006 streamflow was 23 to 34 percent of the WYs 2007 and 2008 average flows and for the Little Blue River relative flows were also smaller, between 15 and 20 percent of the WYs 2007 and 2008 flows. Average daily and monthly streamflow at all sites for July 2005 through December 2008 are shown in figure 9. Data are available from the USGS at *http://waterdata.usgs.gov/mo/nwis/sw/*.

Precipitation, both annual and monthly, was less in 2006 than in 2007 and 2008. The 2006 precipitation measured at NWS cooperative station 234154 in Independence (fig. 2) was less than average, 66.8 cm, as compared to 125.2 cm and 146.8 cm in 2007 and 2008 (National Climatic Data Center, 1979–2008). The precipitation and streamflow shown in figure 10 for the study period and the previous 30-year averages at the USGS streamgage for the Little Blue River at site 6 indicates a strong positive relation between local precipitation and streamflow. Streamflow and precipitation data indicate that 2005 and 2006 had mostly less than average streamflow and precipitation (with the exception of August 2005) as compared to the 30-year average, whereas 2007 and 2008 had near normal or greater than average streamflow and precipitation.

The percentage of time various daily values of streamflow were exceeded at the study sites are shown in the duration curves in figure 11. Streamflow for the Little Blue River (sites 3 and 6) was not less than about 6 ft^3/s because of the maintenance of low-flow releases from Longview Lake.

Average daily flow yields (the average daily flow in cubic feet per second divided by the drainage basin area in square kilometers times a conversion factor to normalize units) for the study period were smallest for Rock Creek (site 1, 0.061 cm) and largest for Crackerneck Creek (site 4) and the Little Blue River at site 6 (0.084 cm). Flow yields for Rock Creek likely were smaller because of a greater proportion of precipitation and groundwater in the basin entering older sections of the sanitary sewer system that discharges after treatment downstream from the Rock Creek streamgage (site 1). Flow yields for the study period increased downstream for the Little Blue River from 0.074 cm at site 3 to 0.084 cm at site 6 because of the larger percentage of impervious surface in the developed areas downstream from the reservoirs (fig. 3).

Continuous (15-minute) physical properties and dissolved oxygen concentration were recorded at three sites; the Little Blue River sites 3 and 6, and Spring Branch Creek, site 5. Daily values for turbidity, dissolved oxygen, pH, specific conductance, and water temperature at the three sites were computed from the measured data and are summarized in table 5 (at the end of this report) and presented in duration curves in figure 12.

Turbidity in water is caused by the presence of suspended and dissolved matter such as clay, silt, finely divided organic matter, plankton, other microscopic organisms, organic acids, and dyes (American Society for Testing Materials International, 2002). Turbidity in small streams affects biotic communities, decreases diversity of fish and other animal communities, and lessens the productivity of aquatic populations (Waters, 1995). Higher turbidity also inhibits light penetration and photosynthesis, which can damage benthic habitats and interfere with feeding activities of aquatic organisms (Davies-Colley and Smith, 2001). Measurements of turbidity in surface water are used to characterize the clarity of the water and can be used as an indicator of the condition and health of a stream. Turbidity as a surrogate for suspended sediment concentrations in regression models has been used for some time (Gray and Glysson, 2003) and is used in this report as a variable in load regression models of nutrients and *E. coli*.

The EPA has developed recommended ambient water-quality standards for each designated nutrient ecoregion in the nation (U.S. Environmental Protection Agency, 2000). The

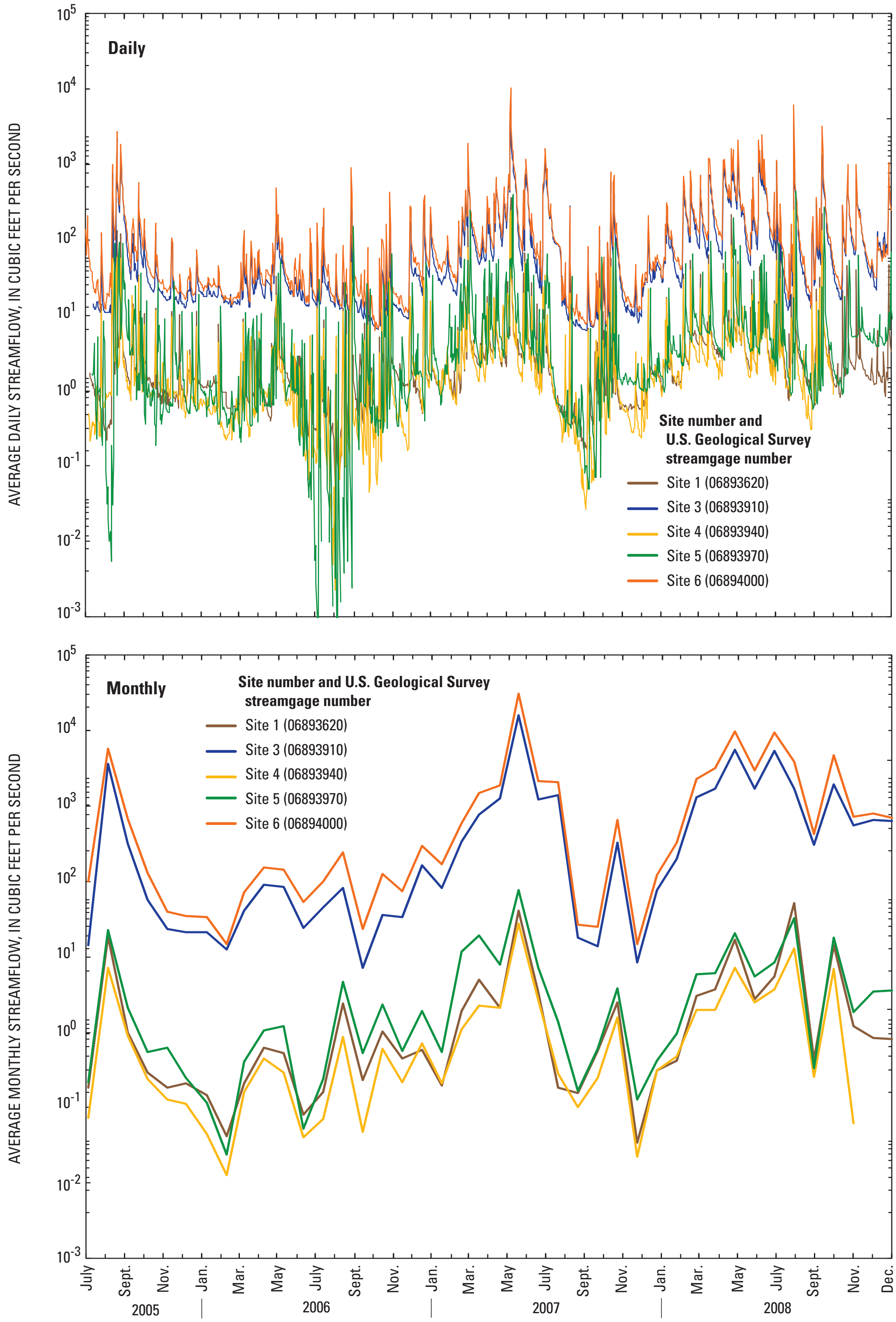


Figure 9. Average daily and monthly streamflow by site, July 2005 through December 2008.

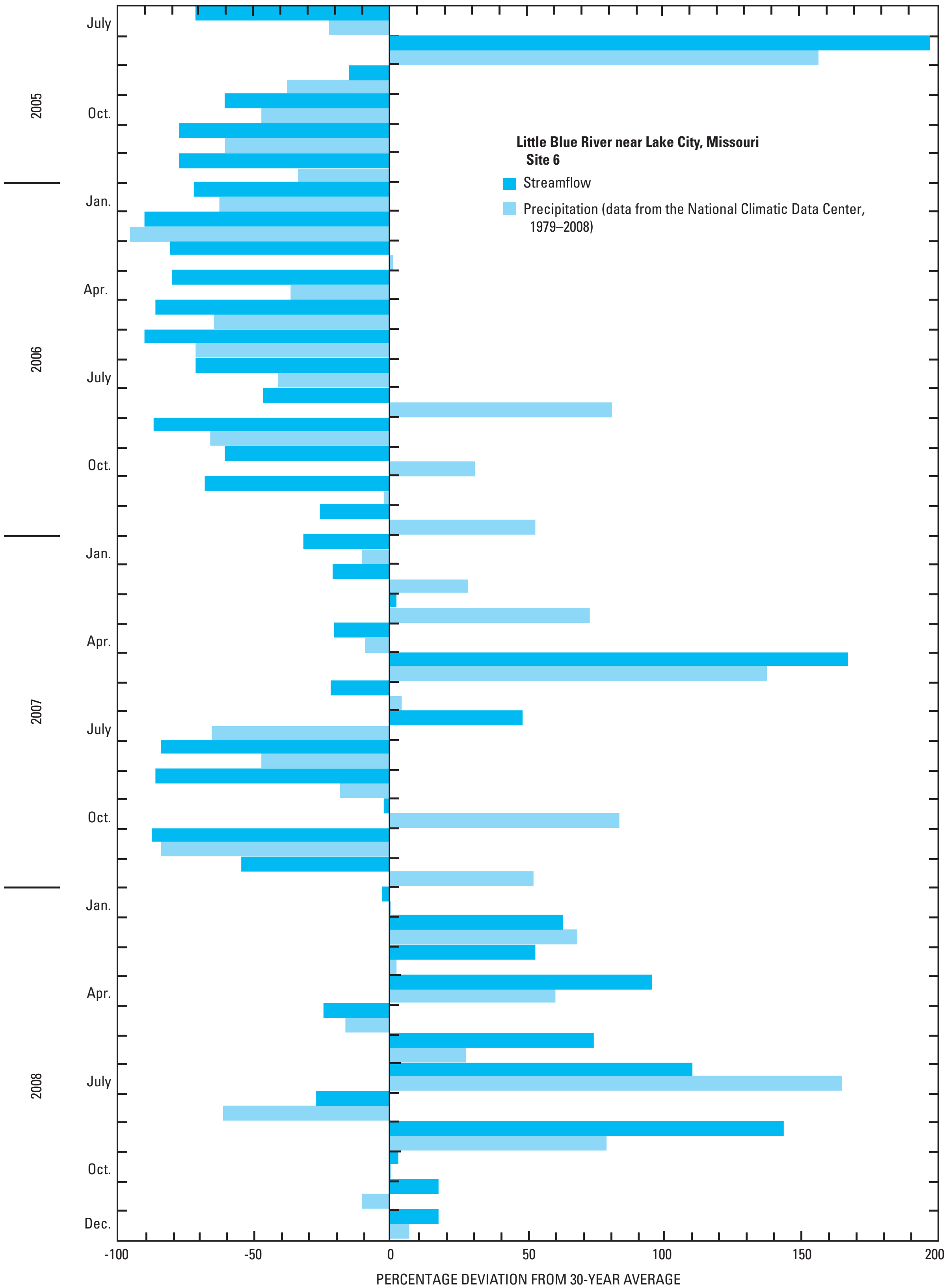


Figure 10. Percentage deviations from the 30-year average monthly streamflow at Little Blue River near Lake City, Missouri, compared with the 30-year average monthly precipitation measured and recorded at Independence, Missouri, July 2005 through December 2008.

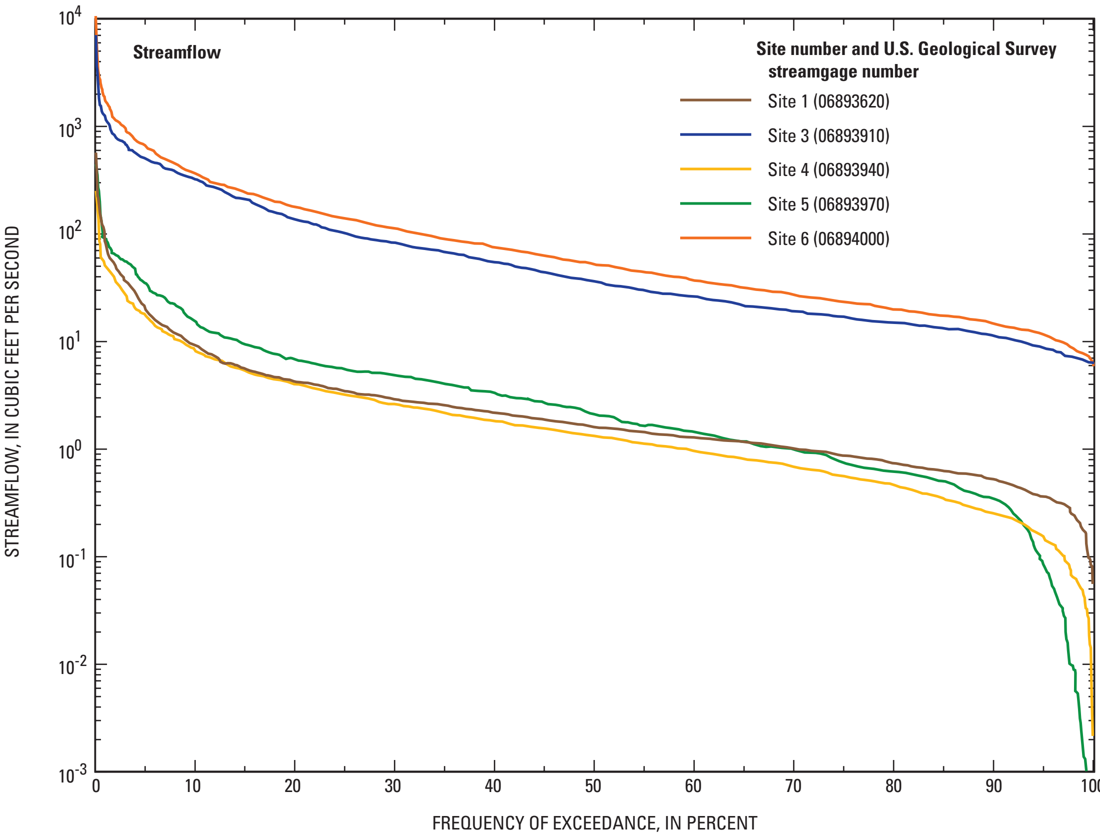


Figure 11. Frequency of exceedance for measured average daily streamflow at streamgages in Independence, Missouri, July 2005 through December 2008.

EPA level III ecoregion 40 (includes the study area) recommended guideline for turbidity is 15.5 nephelometric turbidity units (NTU). This guideline was developed as a standard for comparison of the response of algal growth to increased nutrient loadings to streams and the resultant increases to turbidity in streams. It was beyond the scope of this study to differentiate turbidity attributable to algae or to suspended sediment. The 15.5-NTU guideline is considered a reference only and in context with streamflow. Daily turbidity at sites with CWQMs (sites 3, 5, and 6) exceeded 15.5 NTU between about 40 and 60 percent of the time (fig. 12), including periods of low flow when algal growth may have been a contributing factor. However, most episodes of elevated turbidity were attributable to larger suspended sediment concentrations during and after storms.

Turbidity measurements for the streams in this study were observed to increase almost immediately and proportionally to increases in streamflow as shown in figure 13. Average daily turbidity ranged from 2.2 NTU at site 5 to 970 NTU at site 6 (table 5). The maximum values that the sensors used in this study were capable of reading (about 1,200 to 1,400 NTU) were exceeded on occasion, so that the maximum daily values on several days may have been greater. However, this limitation of the sensors may not be important when evaluating stream health. Periods of extreme high turbidity of short duration may not be as important as periods of moderate turbidity of longer duration because periods of increased, but moderate turbidity that persist can have a greater effect on species diversity and benthic habitat (Davies-Colley and Smith, 2001; Shaw and Richardson, 2001; Bonner and Wilde, 2002).

Many chemical and biological reactions in surface water depend directly or indirectly on dissolved oxygen. Dissolved oxygen is necessary for the survival and growth of many aquatic organisms. Sources of dissolved oxygen in water include atmospheric reaeration and photosynthetic activity (U.S. Geological Survey, variously dated). Missouri standards for AQL require that dissolved oxygen concentrations be 5 mg/L or greater for streams designated as warm-water fisheries such as the Little Blue River (Missouri Department of Natural Resources, 2005–2009). Extreme average daily values for dissolved oxygen concentration ranged from 1.2 to 18.7 mg/L (table 5). Daily dissolved oxygen concentrations were less than 5 mg/L between less than 2 percent of the time for the Little Blue River (sites 3 and 6) to about 5 percent of the time in the smaller Spring Branch Creek (site 5, fig. 12). Spring Branch Creek had more frequent periods of stagnant flow conditions than the Little Blue River sites (fig. 11) for which minimum flows are maintained with controlled releases from Longview Lake. Typically, as water temperatures increase seasonally in late spring and summer, average dissolved oxygen concentrations decline in streams. The streams in the study area, including the Little Blue River, follow this pattern. This relation for 15-minute dissolved oxygen concentration with water temperature and streamflow for the Little Blue River at site 6 during April through June 2008 is shown in figure 14. Dissolved oxygen is suppressed during peak flow (fig. 14) when suspended sediment concentrations and

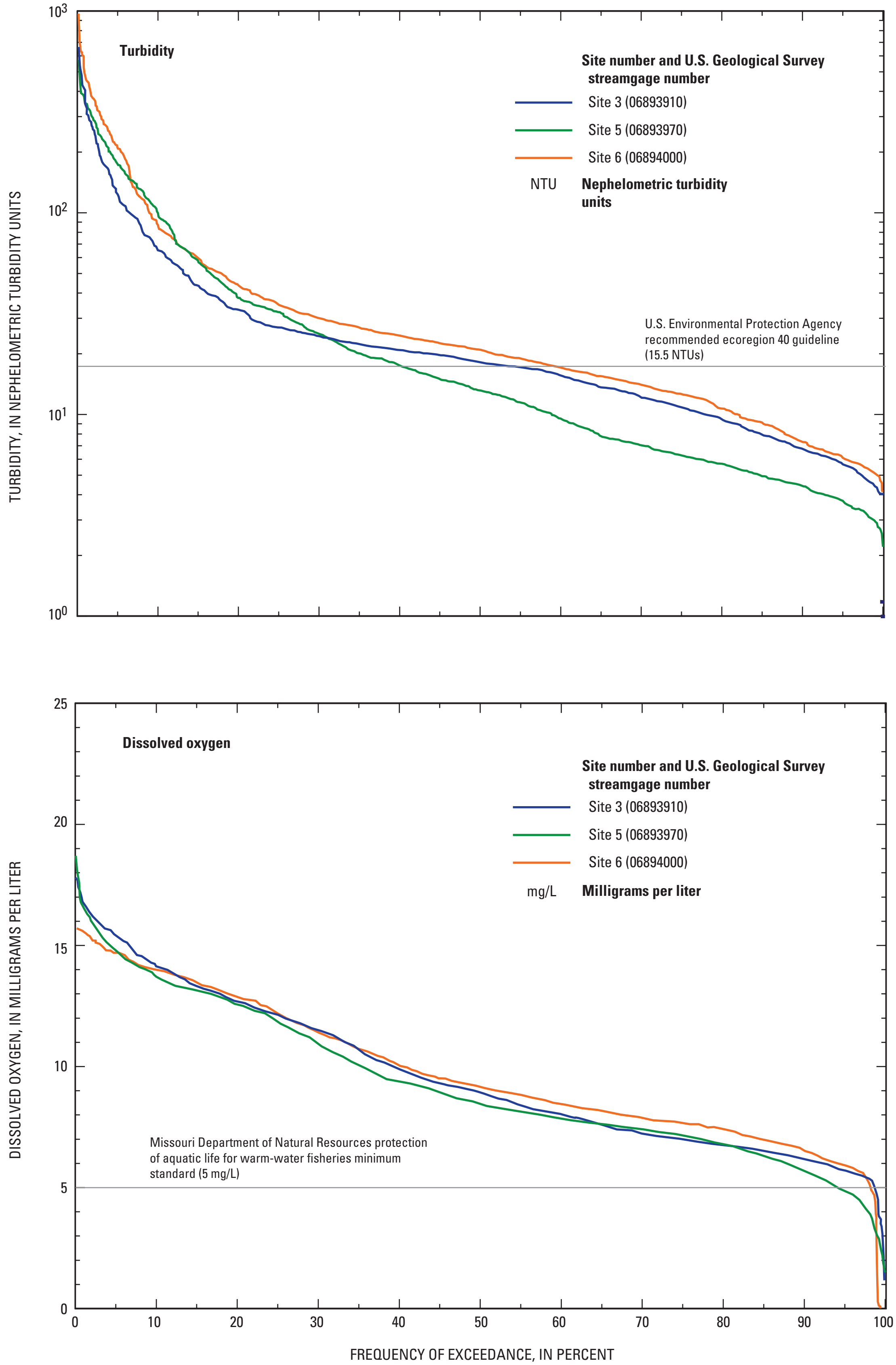
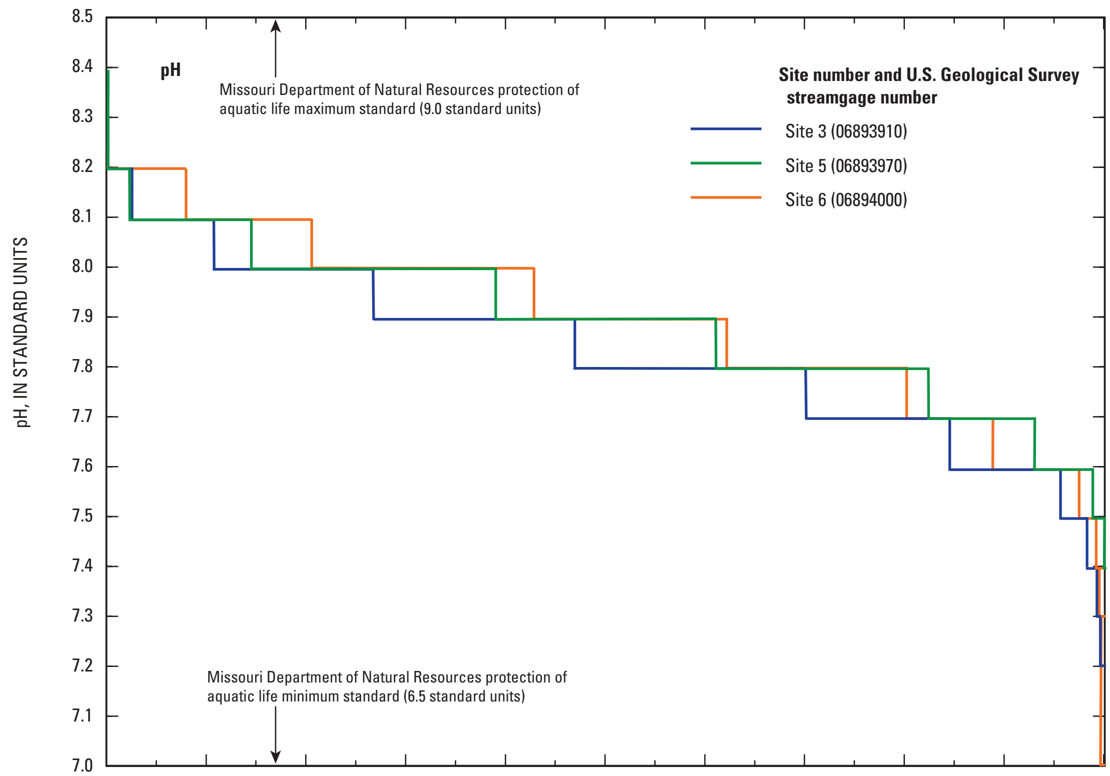


Figure 12. Frequency of exceedance for average daily turbidity, dissolved oxygen, pH, specific conductance, and water temperature, at sampling sites equipped with continuous water-quality monitors in Independence, Missouri, July 2005 through December 2008.



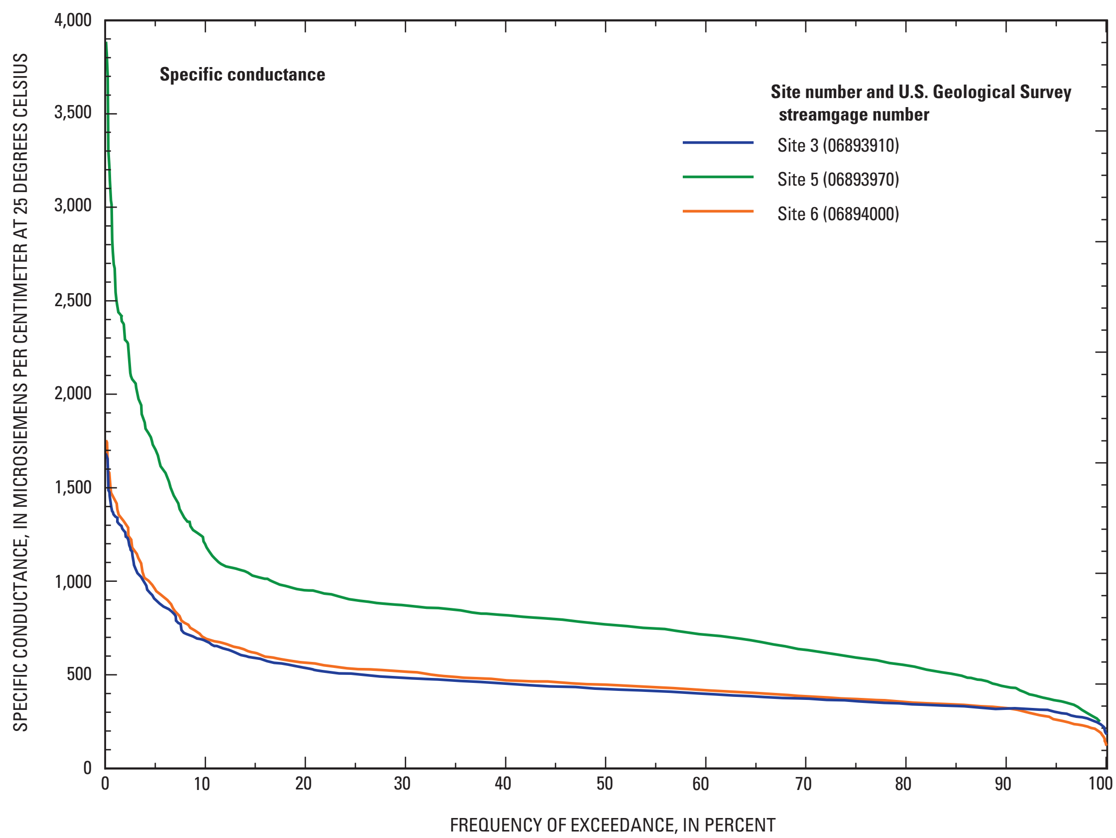


Figure 12. Frequency of exceedance for average daily turbidity, dissolved oxygen, pH, specific conductance, and water temperature, at sampling sites equipped with continuous water-quality monitors in Independence, Missouri, July 2005 through December 2008.—Continued

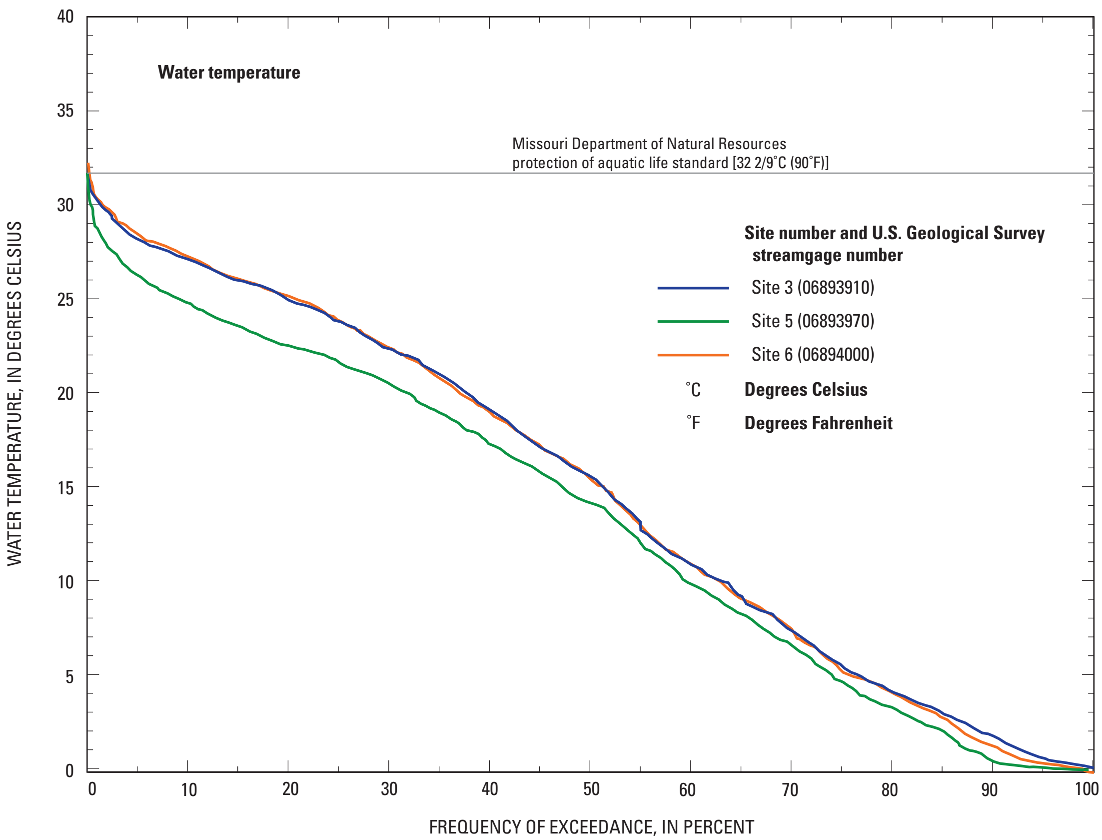


Figure 12. Frequency of exceedance for average daily turbidity, dissolved oxygen, pH, specific conductance, and water temperature, at sampling sites equipped with continuous water-quality monitors in Independence, Missouri, July 2005 through December 2008.—Continued

turbidity (fig. 13) are correspondingly large. Diurnal fluctuations in dissolved oxygen also are suppressed after storms and increase gradually afterward as suspended sediment decreases, light penetration increases, and photosynthetic activity of benthic and planktonic algae resumes. Small dissolved oxygen concentrations also occurred during the winter on the smaller stream, Spring Branch Creek (site 5; data on file at the USGS Water Science Center office in Lee's Summit), most likely because of a combination of low flows, ice cover, and organic decay in streambed sediments.

The pH of surface water generally ranges from 6.5 to 8.5 standard pH units (Hem, 1992). Missouri standards for AQL require that water contaminants not cause the pH to be outside of the range of 6.5 to 9.0 (Missouri Department of Natural Resources, 2005–2009). Daily values for pH ranged from a minimum of 7.0 for the Little Blue River at site 6 to a maximum of 8.4 for Spring Branch Creek (site 5). The duration curve for pH (fig. 12) shows no daily values outside the range of Missouri's AQL standards, and no continuous pH values were recorded outside of the range.

Specific conductance is a surrogate measurement for the concentration of ionized constituents in stream water (U.S. Geological Survey, variously dated). Specific conductance in streams is affected by the soil and rock composition underlying the basin, amount and intensity of precipitation, point-source contamination, and nonpoint source runoff (Dow and Zampella, 2000; McMahon and Cuffney, 2000). Under natural conditions, specific conductance is greater during low streamflow because of groundwater contributions to streamflow and less during high streamflow because of dilution from precipitation (fig. 15). However, specific conductance in urban streams can become elevated in the winter because of runoff to streams after the application of road salt and other de-icers to city streets and remain elevated after runoff to streams has ceased (Cooper and others, 2008).

Large specific conductance mostly is related to the application of road salt in urban areas during the winter, but the effects of road salt can persist throughout the year because of storage in pavement depressions and various drainage catchments (Ostendorf and others, 2006). Spring Branch Creek had the largest instantaneously recorded specific conductance of 4,060 microsiemens per centimeter at 25 °C (μS/cm) after the application of road salt to streets and highways in January 2007, whereas the highest recorded value for the Little Blue River sites 3 and 6 was 2,510 μS/cm, also during the winter of 2007. Spring Branch Creek consistently had larger specific conductance values than the Little Blue River sites because of the larger percentage contribution of groundwater to base flow and more direct runoff of high specific conductance meltwater to the smaller and more urbanized stream with 57.6 percent developed land-use classifications (U.S. Geological Survey, 2001; fig. 3). Downstream the Little Blue River at site 6 had marginally larger specific conductances than upstream site 3 over most of the observed range of values (table 5, fig. 12). Larger observed specific conductance values for the Little Blue River at downstream site 6 can be attributed

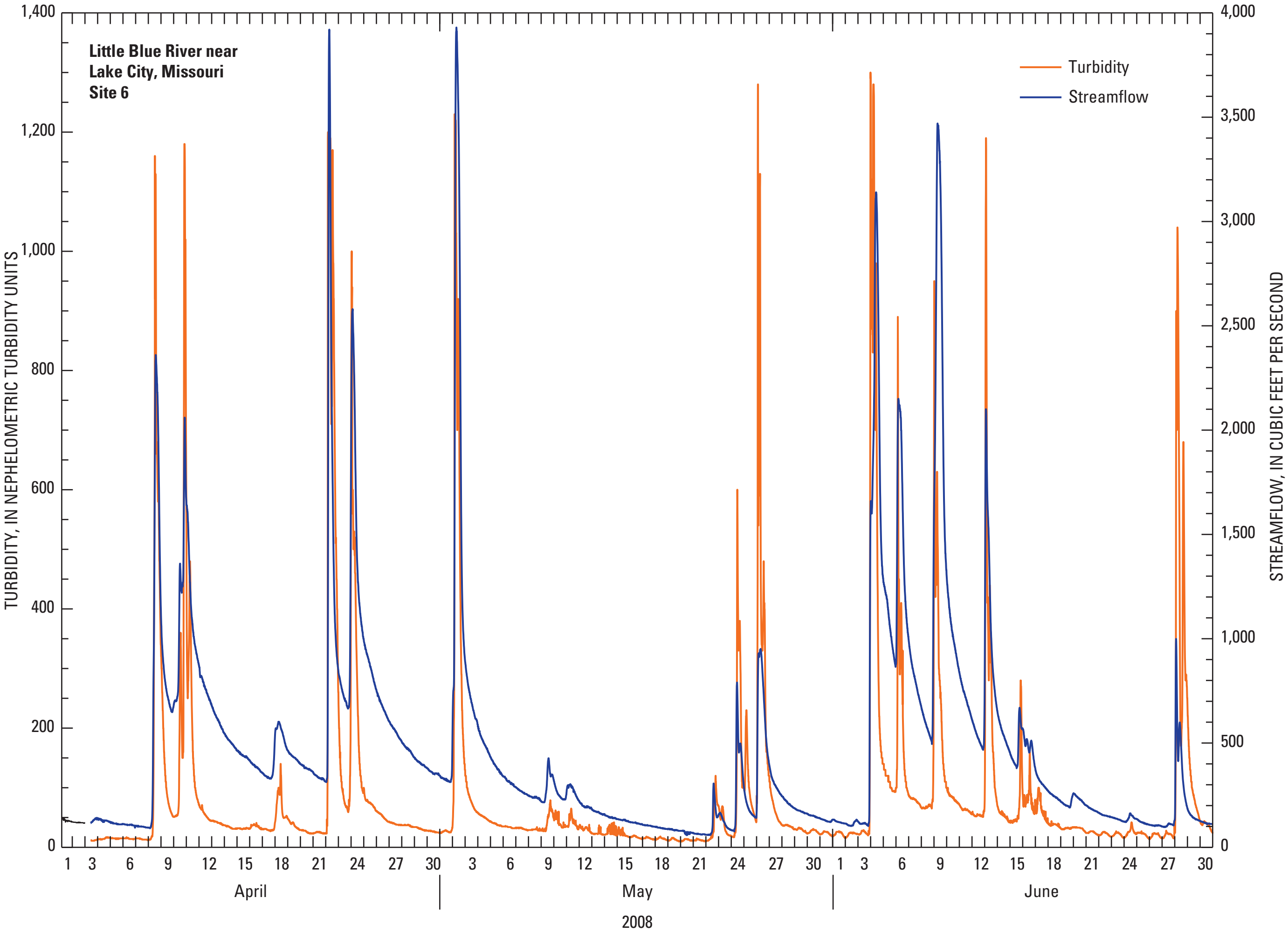


Figure 13. Continuous (15-minute) measured turbidity and streamflow at Little Blue River near Lake City, Missouri, April through June, 2008.

to the contributions from the more urbanized smaller streams, including Crackerneck Creek (site 4) and Spring Branch Creek (site 5).

The Missouri standard for AQL in warm-water streams for water temperature is 32 2/9 °C (90 °F; Missouri Department of Natural Resources, 2005–2009). Daily values for water temperature ranged from about 0 °C for the three CWQM sites to 32.2 °C for the Little Blue River at site 6. The extreme high water temperature recorded was 35.6 °C at site 6 during low flow in July 2006. The duration curves for average daily water temperature (fig. 12) show only infrequent (<1 percent) exceedance of the Missouri standard for AQL. However, continuous 15-minute data (data on file at the USGS Water Science Center office in Lee's Summit) show more frequent exceedance, but of short diurnal duration, during hot weather and low flow in the summer at Spring Branch Creek.

Base-Flow Water Quality

Twenty-five base-flow water-quality samples were collected at streamgage sites (table 1) beginning in June 2006. Samples were collected during three seasonal periods; a spring and early summer high runoff season (March through July), a late summer and fall transitional season (August through October), and a low runoff winter season (November through February). Most of the samples (13) were collected during the transitional season with the remainder split between the winter (5) and spring early summer (7) seasons. Data collected included streamflow, physical properties, dissolved oxygen, chloride, metals, nutrients, suspended sediment, OMCs, and fecal indicator bacteria (tables 6 and 7, at the end of this report). Results of the bacteria sampling are discussed separately later in the report.

Streamflow at each site was measured at the time of sampling or was determined from an established stage-discharge relation (Rantz and others, 1982) at the individual sites to calculate instantaneous loads and yields of selected constituents. The reservoirs, Blue Springs Lake and Longview Lake, on the Little Blue River upstream from Independence affect base flow. Blue Springs Lake and Longview Lake both have fixed and low-flow controls. Low-flow controls are used to maintain minimum flows and on occasion to lower pool elevation. Water releases from Longview Lake at low flow are

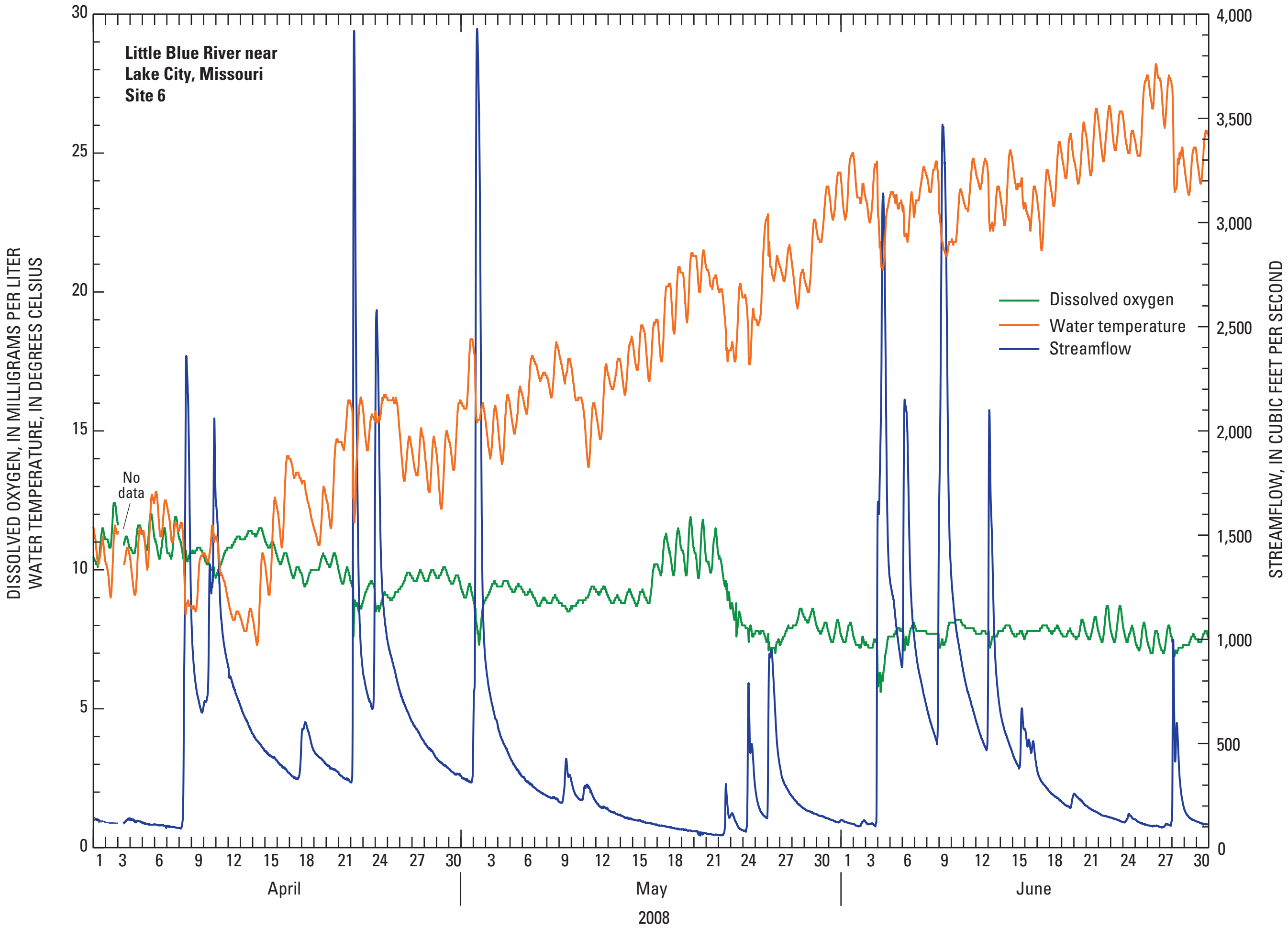


Figure 14. Continuous (15-minute) measured dissolved oxygen concentration, water temperature, and streamflow at Little Blue River near Lake City, Missouri, April through June 2008.

maintained at a minimum of about 7 ft^3/s. Low-flow releases are not maintained for Blue Springs Lake.

Physical Properties, Dissolved Oxygen, and Inorganic Constituents

Physical properties, pH, specific conductance, and temperature, were measured at all sites, and turbidity and dissolved oxygen at sites 3, 5, and 6 with CWQMs during base-flow sampling. Base-flow measurements varied within normal ranges for environmental waters (Hem, 1992; table 6). Turbidity ranged from 7.0 to 35 NTU and dissolved oxygen from 5.1 mg/L to 14.3 mg/L. The pH varied in a narrow range from near neutral (7.2) to slightly alkaline (8.1). Specific conductance for most samples, except those collected in December 2006, ranged from 382 to 859 µS/cm. Samples collected December 5, 2006, had larger specific conductances that ranged from 873 to 1,720 µS/cm likely because of road salt applied during freezing precipitation the previous week. Water temperatures at the time of base-flow sample collection ranged seasonally from a low of 0.7 °C in December 2006 to a high of 30.5 °C in August 2007.

Chloride concentrations in base flow ranged from 23.6 to 329 mg/L. Chloride concentrations from the streams draining Independence (sites 1, 4, and 5; fig. 16) that were larger than the Missouri chronic standard for AQL of 230 mg/L (Missouri Department of Natural Resources, 2005–2009) were measured in December 2006. Similar to the specific conductance values discussed previously, the larger chloride concentrations likely were because of road salt carried into the streams in runoff the previous week. Chloride concentrations in base flow for the Little Blue River were marginally smaller.

Base-flow samples were analyzed for the total recoverable metals (unfiltered sample that includes dissolved and suspended metals); aluminum, arsenic, cadmium, chromium, copper, lead, mercury, and zinc, that may have a toxic effect on stream biota when present in sufficient bioavailable concentrations. However, the bioavailability of metals (the proportion of total metals available for incorporation into biota) is complex and dependent on many interrelated chemical, biological, and environmental processes (Tessier and Campbell, 1987). Total metal concentrations do not necessarily correspond with metal bioavailability (John and Leventhal, 1995). Eggleton and Thomas (2004) state that toxicity studies

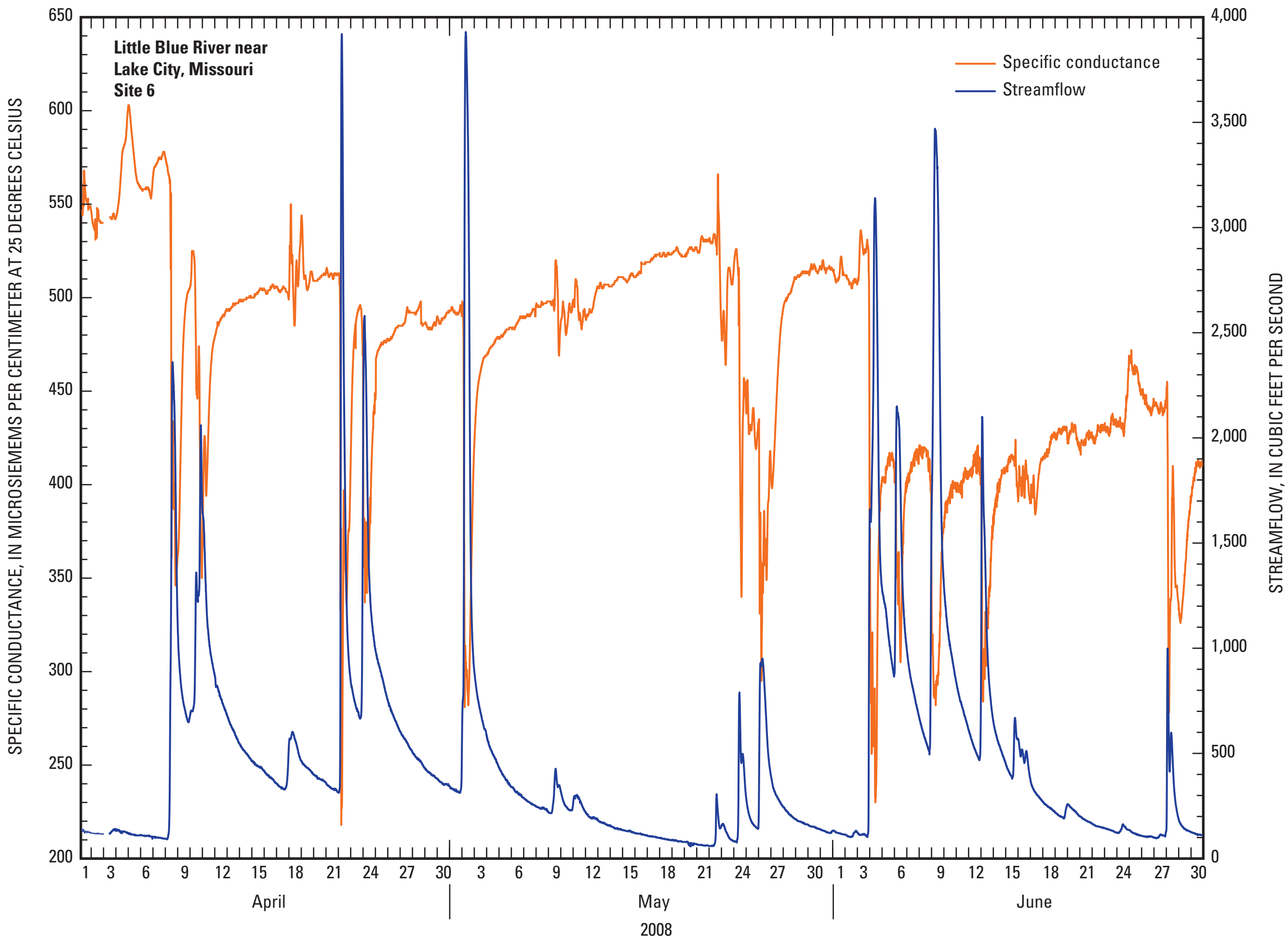


Figure 15. Continuous (15-minute) measured specific conductance and streamflow at Little Blue River near Lake City, Missouri, April through June, 2008.

show that the concentrations of metals bioavailable as the result of sediment disturbance (suspended sediment) are not sufficient to be acutely toxic, although chronic effects have been observed. Generally, the dissolved metal fraction of total metal concentration is more readily available for uptake by stream biota (Traina and Laperche, 1996), whereas metals adsorbed to sediments or in solid form are less available (John and Leventhal, 1995). The Missouri standards for AQL are for dissolved metal concentrations, except for mercury, that is a total (dissolved and suspended) standard (Missouri Department of Natural Resources, 2005–2009). Concentrations of total recoverable metals in base-flow samples were generally small (table 6) because of small suspended sediment concentrations and were less than the Missouri standard for AQL for dissolved metals. Suspended sediment concentrations ranged from 10 to 138 mg/L (table 6; fig. 17). Larger suspended sediment concentrations (greater than about 50 mg/L) in base flow in smaller streams (sites 1, 4, and 5) were likely because of prior disturbance either in or upstream from the pools being sampled. The fine clays that are deposited in stream pools during the recessions of stormflow can be disturbed and remain in suspension for some time.

Nutrients

Nutrients such as N and P are essential for all plant and animal life. However, in excess amounts, nutrients can accelerate the growth of algae and consume dissolved oxygen to the detriment of water quality and stream health. Measured nutrient concentrations in base-flow samples were likely attributable to several nonpoint sources including: atmospheric deposition (table 4); decomposition of plants, yard waste, and other organic matter; leaky sewer lines; fertilizers leached from soils; and residual effects from SSOs.

Nutrients can occur in several forms in surface water and can change phase as they interact with the environment. Once nutrients have entered the stream, they are subject to alteration. Organic N and NO_2 are unstable in aerated water and generally are considered to be indicators of contamination through disposal of sewage or organic waste (Hem, 1992). Atmospheric deposition of N (table 4) is a substantial source of total N in streams (Clark and others, 2000; Alexander and others, 2008). Most P in base-flow samples is dissolved P in the form of orthophosphate (ortho P) and is available for uptake by plants and algae (Hem, 1992). The availability of

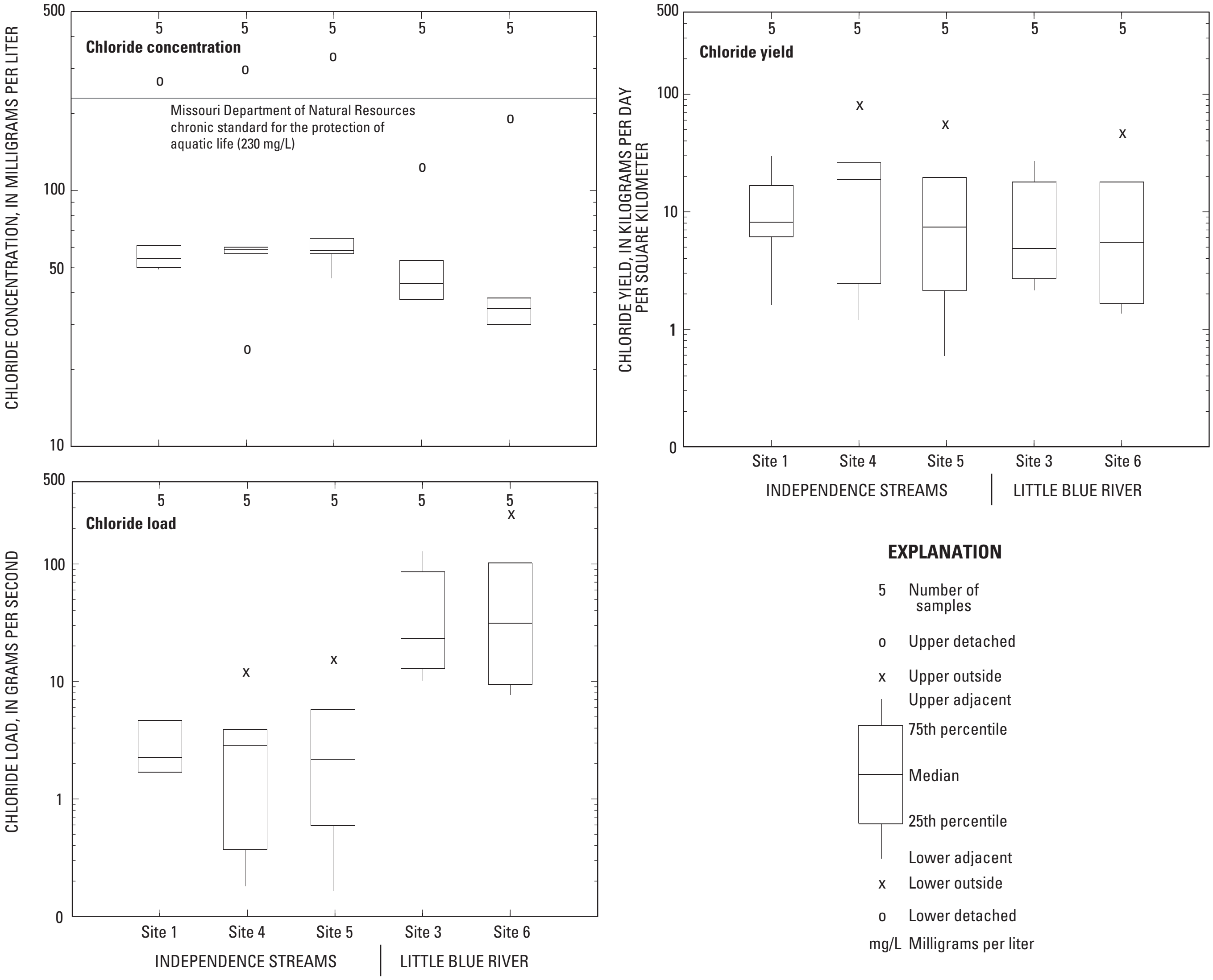


Figure 16. Chloride concentrations and calculated instantaneous loads and yields in base-flow samples by site, June 2006 through September 2008.

P generally is thought to be a critical factor in eutrophication (excessive algal growth accompanied by small dissolved oxygen concentrations) of water bodies, as the nutrient in shortest supply will tend to be the control on algal growth rates. Thus, a decrease in P may decrease productivity more quickly than would be possible by altering the influx of readily available N. Total N and particulate organic nitrogen (org N) and total P (dissolved and particulate) concentrations, loads, and yields in base-flow samples are summarized in table 6 and figures 18 and 19.

Missouri has not established nutrient standards for surface-water streams. The EPA has proposed provisional nutrient standards for level III ecoregion 40 streams, including the study area, of 0.86 mg/L for total N and 0.09 mg/L for total P (U.S. Environmental Protection Agency, 2000). However, the average annual precipitation-weighted concentration of dissolved N (NH_4 plus NO_3) at five surrounding National Atmospheric Deposition Program (NADP) sites (table 4) for 2005 through 2008 is 0.64 mg/L (National Atmospheric Deposition Program/National Trends Network, 2009), a substantial contribution to background concentrations and observed concentrations of dissolved N in stormflow. The NADP does not collect data for dissolved P in precipitation. Nutrient concentrations in base-flow samples collected for the streams draining Independence (sites 1, 4, and 5), exceeded the EPA standard for total N and total P in about 90 percent of samples. Base-flow samples collected at the two Little Blue River sites (3 and 6) exceeded the total N and total P standard about 30 percent of the time. The median instantaneous total N load in base flow increased downstream for the Little Blue River at site 3 [0.39 gram per second (g/s)] to site 6 (0.71 g/s), likely caused by inputs from tributary streams, including two streams that drain developed areas of Independence (fig. 3). These streams are Crackerneck Creek (site 4) and Spring Branch Creek (site 5) that contribute about 38 percent of the increased median instantaneous load. However, the median yields of total N in base flow for the two

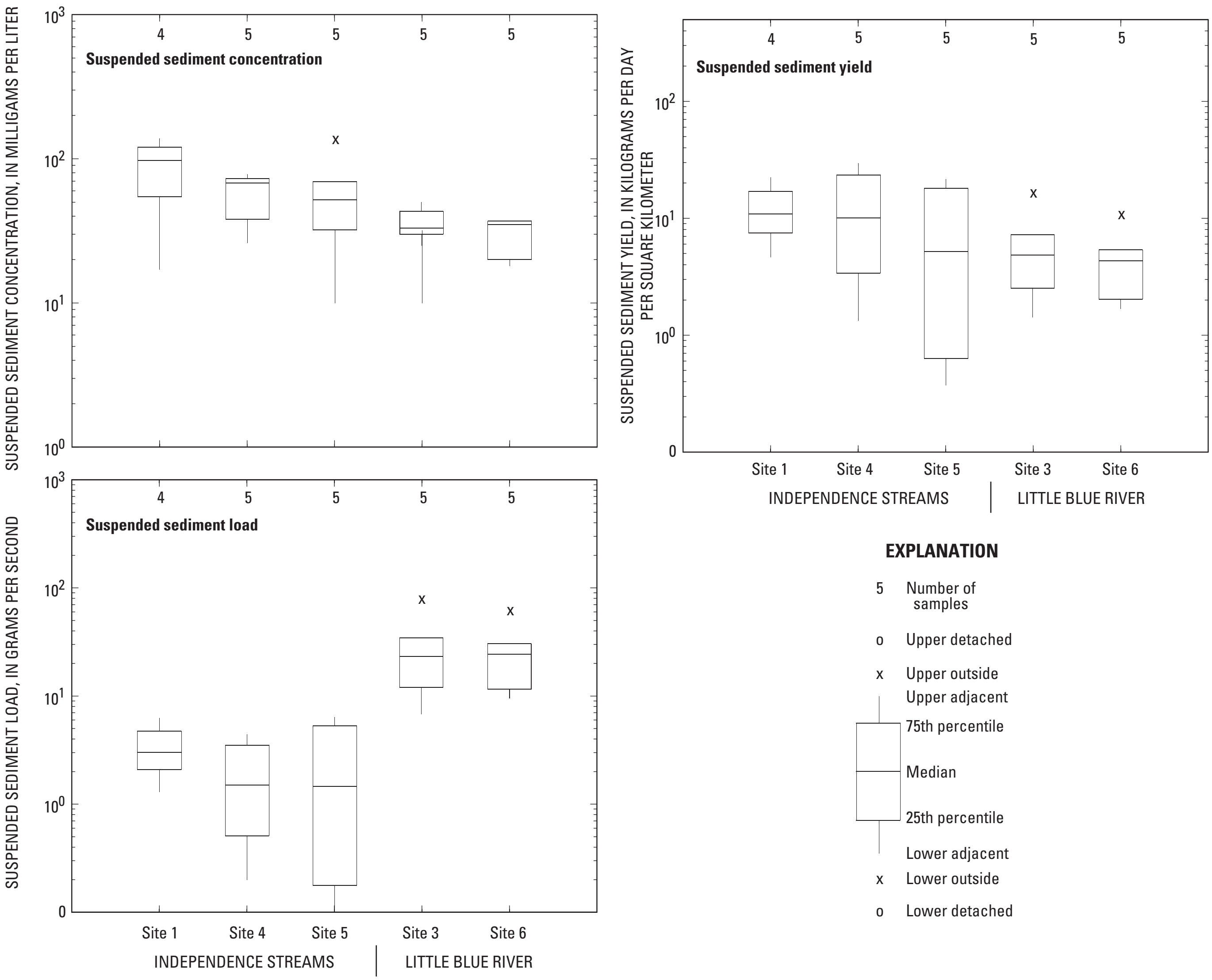


Figure 17. Suspended sediment concentrations and calculated instantaneous loads and yields in base-flow samples by site, June 2006 through September 2008.

urban streams were not significantly larger (p=0.37) than for the Little Blue River upstream from site 3 (fig. 18).

Common Organic Micro-Constituents

A total of 24 base-flow samples were analyzed for OMCs between June 2006 and September 2008 (table 7). Two categories of OMCs (table 2) had samples with detections in base flow more than one-half the time, pesticides (100 percent) and plastics (67 percent). Most detections were near or less than the NWQL LRL and not quantified (data on file at the USGS Water Science Center office in Lee's Summit). The most frequently detected pesticides were 3-4-dichlorophenyl isocyanate (71 percent), prometon (67 percent), atrazine (58 percent), and DEET (42 percent). One sample from Crackerneck Creek in August 2007 had a detection of 53.3 µg/L of 3-4-dichlorophenyl isocyanate (average detection for all sites 1.00 µg/L). One possible source is a degradation product of diuron, a common pre-emergent herbicide. The plasticizer tris(2-butoxyethyl) phosphate was detected at small concentrations in 50 percent of samples.

The median total OMC concentration for all samples was 1.77 µg/L as compared to the 4.46 µg/L reported by Wilkison and others (2006) for sites with no apparent wastewater sources in the adjacent Blue River Basin. Data were collected from 1998 to 2004, and indicated fewer or smaller potential sources of OMCs in the Little Blue River Basin than the Blue River Basin. Instantaneous loads in base flow for Independence streams calculated from the summed concentrations of all OMCs (total OMCs) were small, ranging from a minimum of 0.01 to a maximum of 4.67 milligrams per second (mg/s). The Little Blue River sites had the largest loads in base flow with median instantaneous loads of 1.71 mg/s at upstream site 3 and 0.70 mg/s at downstream site 6. The smaller loads calculated downstream were most likely because of the small

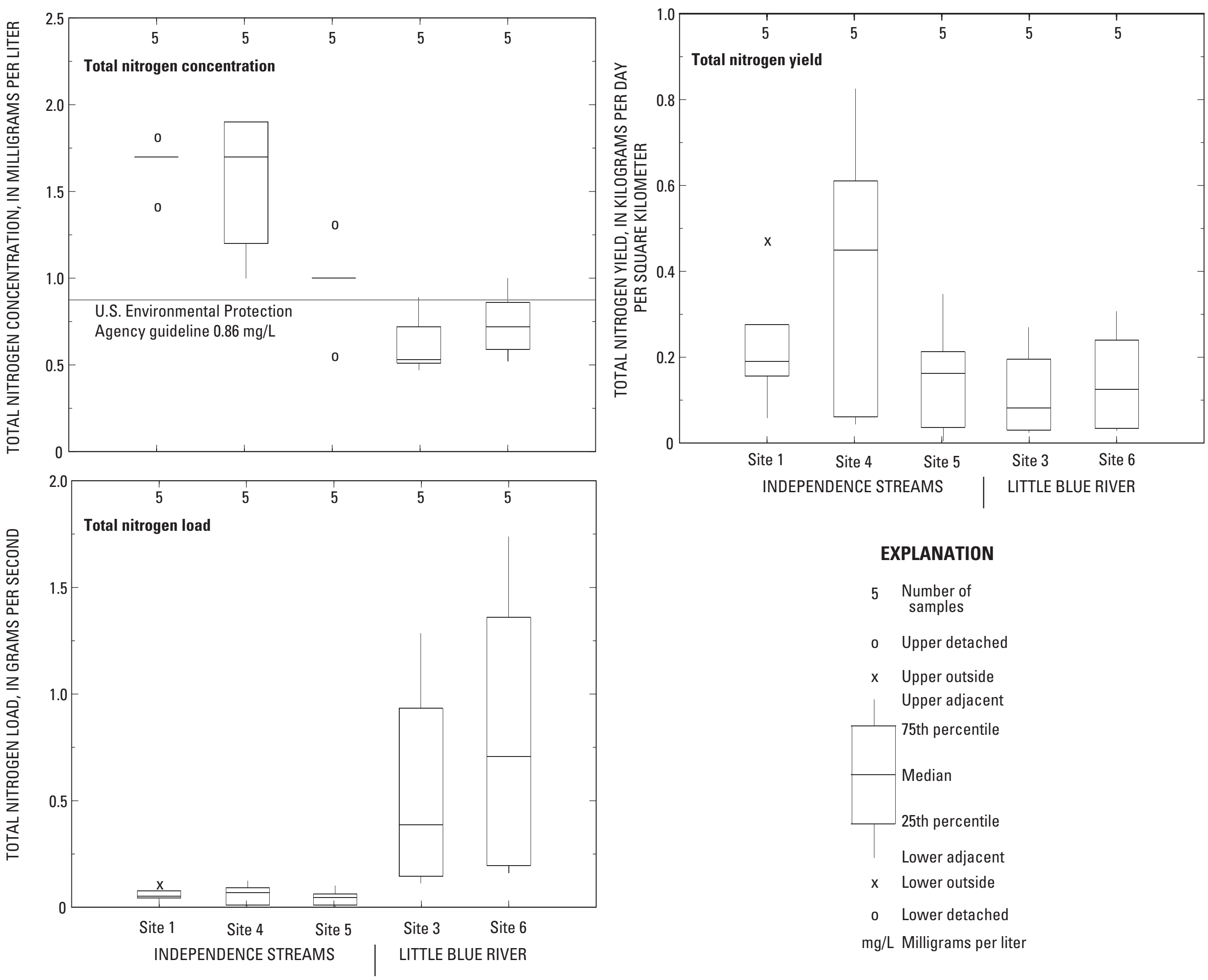


Figure 18. Total nitrogen concentration and calculated instantaneous loads and yields in base-flow samples by site, June 2006 through September 2008.

number of samples and method variability, but the degradation of OMCs in streams cannot be ruled out.

Stormflow Water Quality

A total of 91 stormflow water-quality samples were collected beginning in June 2005 at streamgage sites (table 1). Data collected included streamflow, physical properties, dissolved oxygen, chloride, metals, nutrients, suspended sediment, OMCs, and fecal indicator bacteria (tables 8 and 9, at the end of this report). Results from the bacteria sampling are discussed separately later in this report. Streamflow for samples collected with automatic samplers was calculated as the average streamflow for the sampled interval of the storm. Streamflow for grab samples was measured at the time of sampling or was determined from established stage-discharge relations (Rantz and others, 1982) at the individual sites and used to calculate instantaneous loads of selected constituents.

Blue Springs Lake and Longview Lake affect streamflow and estimates of water-quality constituent loads and yields for the Little Blue River at sites 3 and 6 downstream from the lakes (fig. 1). Infrequently the pool elevations in the lakes are lowered by increasing water releases. Controlled releases only occurred twice during this study for Blue Springs Lake in July 2007 and June to July 2008 (U.S. Army Corps of Engineers, written commun., 2009), but not concurrently with any sampling. For the rest of the study period, streamflow was uncontrolled except for the low-flow releases from Longview Lake. For precipitation and streamflow measured for the Little Blue River at site 6, the percentage of annual streamflow per month exceeded the percentage of annual precipitation from January through June when the pattern was reversed and the percentage of annual precipitation was greater than the percentage

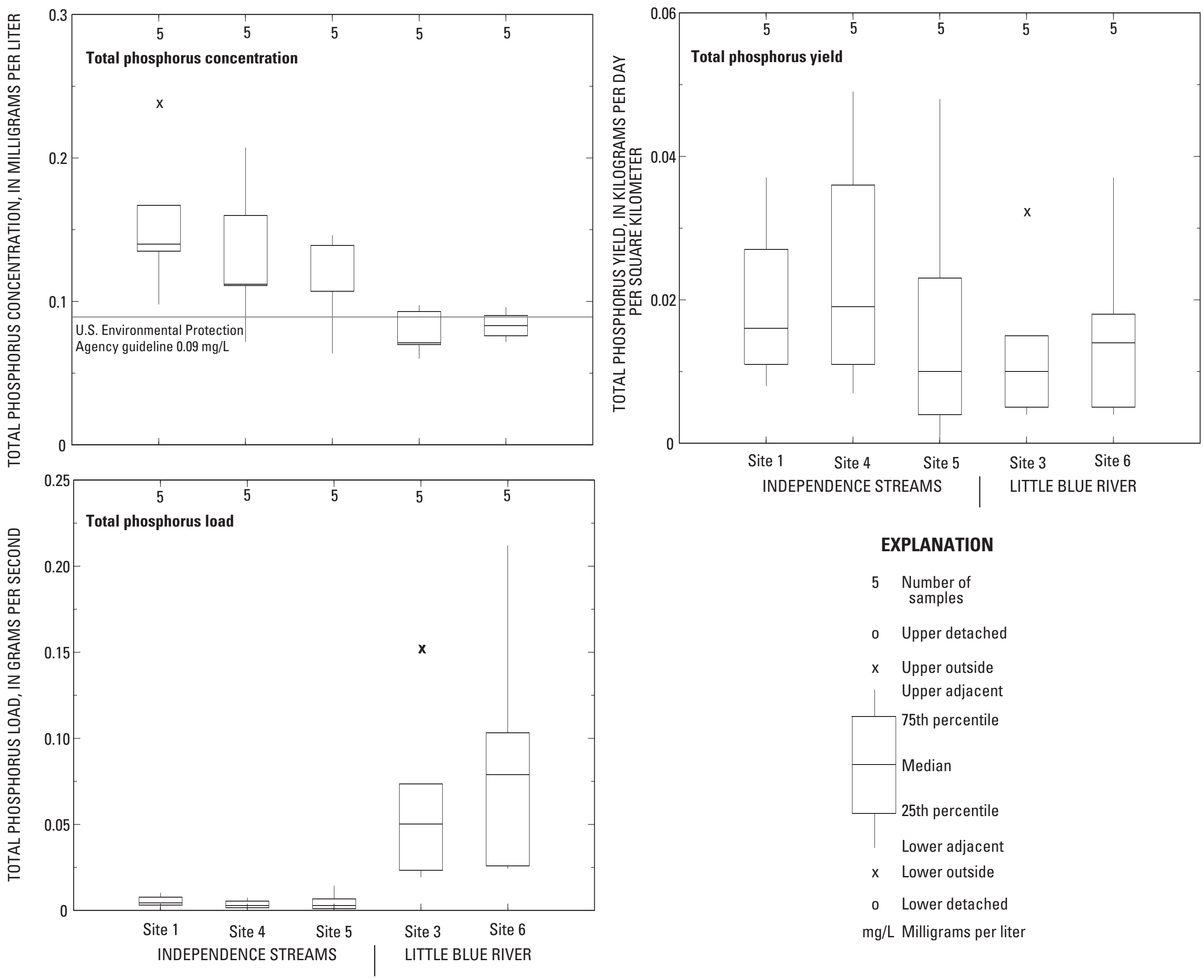


Figure 19. Total phosphorus concentration and calculated instantaneous loads and yields in base-flow samples by site, June 2006 through September 2008.

of annual streamflow per month for July through December (fig. 20). The monthly percentage of annual streamflow would be expected to more closely approximate monthly precipitation without the effect of the lakes. This relation primarily is the result of the retention of runoff in the lakes when water levels are below the elevation of their controls and increased evapotranspiration during the summer and early fall. The natural seasonal variations in runoff, streamflow, and water quality in response to precipitation in the Little Blue River Basin, therefore, are altered to some extent by the lakes upstream from Independence.

Daily, monthly, and annual loads were estimated using both base-flow and stormflow data for chloride, total N, total P, suspended sediment, and *E. coli* (discussed separately) using LOADEST (Runkel and others, 2004) and are presented in table 10. For all constituents analyzed, loads, but not necessarily concentrations, increased downstream for the Little Blue River. Flow-weighted concentrations were calculated from the estimated loads by dividing the average daily load by the average daily streamflow. Estimated yields were calculated by dividing the estimated constituent load for a site by the drainage area of the site. Measurements and estimates of constituent concentrations and bacteria densities indicate that potential exists for decreasing loads and concentrations of some constituents to streams, in particular nutrients, bacteria, and turbidity, associated with suspended sediment in stormflow by the continued implementation of BMPs to decrease sediment loads to streams.

Physical Properties, Dissolved Oxygen, and Inorganic Constituents

The physical properties, pH and specific conductance, were measured from the composite stormflow sample for

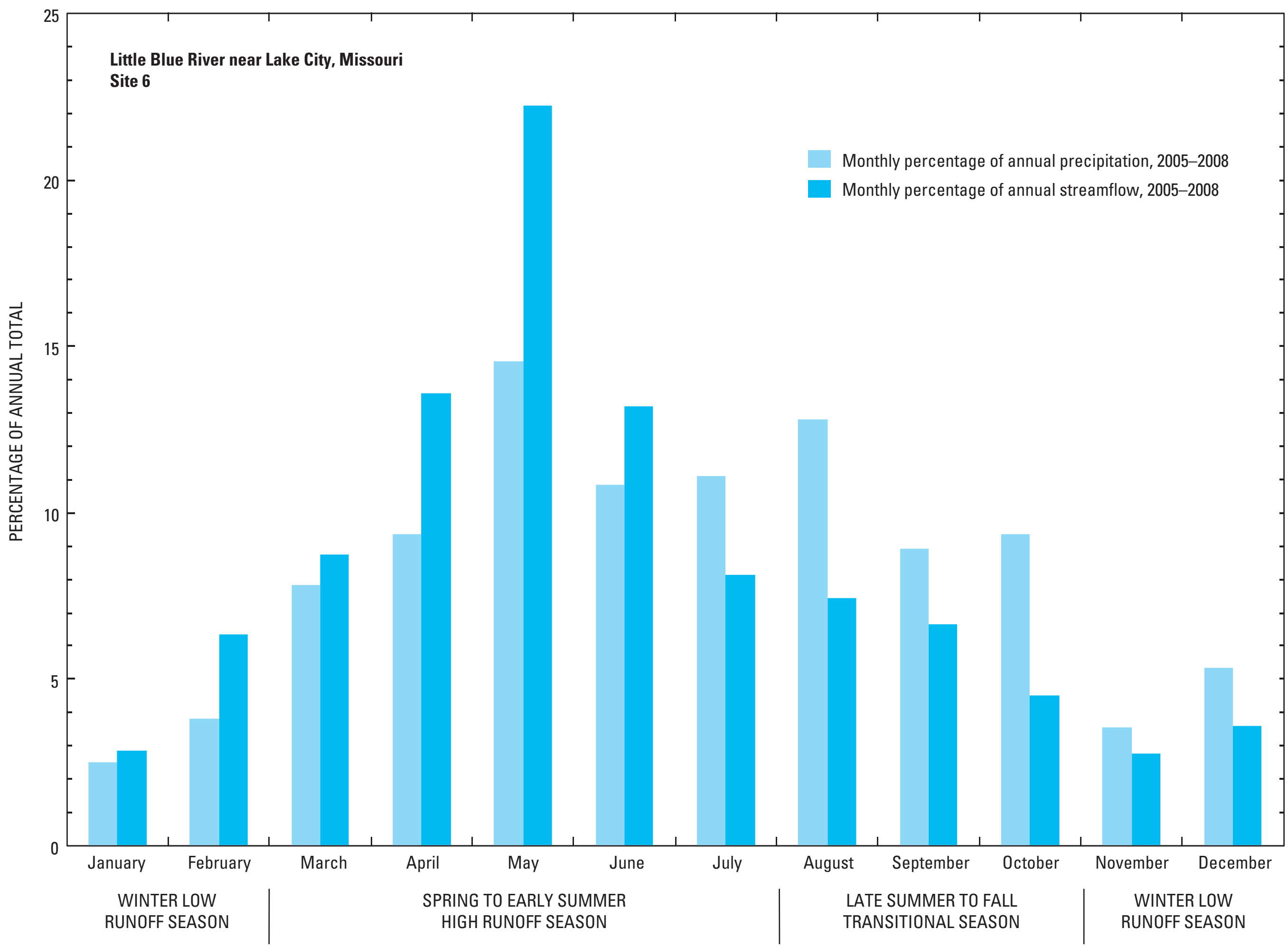


Figure 20. Percentage of total annual precipitation and streamflow by month at Little Blue River near Lake City, Missouri, June 2005 through December 2008.

samples collected with automatic samplers. Average turbidity and temperature for each sampled interval were calculated at the three sites with CWQMs (sites 3, 5, and 6). For grab samples, physical properties and dissolved oxygen concentrations were measured in the stream at the time of sampling. Turbidity in stormflow samples ranged from 9.0 to 1,170 NTU and dissolved oxygen from 5.9 to 12.8 mg/L. The pH at the time of sampling ranged from near neutral 7.1 to 8.2. Specific conductance ranged from 158 to 1,720 µS. Water temperature for stormflow at sites for which in-stream temperature was measured or calculated ranged seasonally from a low of 1.0 °C in December 2007 to a high of 28.3 °C in August 2006 (table 8).

Measured chloride concentrations in stormflow ranged from 6.82 to 463 mg/L. Differences between sites were nearly, but not, significant (p=0.07). The largest chloride concentrations for each site are associated with the December 2007 sampling and likely reflect chloride from road de-icers carried into the streams in runoff the previous week, but no samples exceeded the Missouri acute AQL standard of 860 mg/L (fig. 21). However, larger median instantaneous chloride yields in stormflow for the smaller streams, in particular Spring Branch Creek (site 5; fig. 21), are likely attributable to residual effects from road salt applications during the winter.

Chloride is a naturally occurring constituent in surface water, usually at small concentrations (Hem, 1992). However, large chloride concentrations, especially in urban streams, can occur during the winter months because of the chloride content in road de-icers and can stay elevated for extended periods after application (Dougherty, 2007). Estimated chloride concentrations and loads for July 2005 through December 2008 are shown in figure 22. Uncertainties in the regression models were small with high R^2 between 0.91 and 0.99 and low RMSE between 0.174 and 0.597 (table 10). Seasonal and annual differences in chloride concentrations and loads occurred because of variations in weather, frequency and types of precipitation, and types, rates, and timing of the application of de-icers. Smaller estimated loads for WY 2006 (table 10) are largely caused by the lack of precipitation and runoff during the winter (fig. 10).

Table 10. Regression models for estimating concentrations, densities, and calculated annual loads of selected constituents.

[n, number of samples; R^2, coefficient of determination; RMSE, root mean squared error; ft^3/s, cubic feet per second; Mg, megagram (metric ton); SEP, standard error of prediction; kg/km^2, kilograms per square kilometer; mg/L, milligrams per liter; ln, natural logarithm; L, instantaneous (daily) load; ln(Q), ln(streamflow) minus center ln(streamflow); $ln(Q^2)$, ln of streamflow squared; sin, sine; T, decimal time minus center of decimal time; cos, cosine; SC, specific conductance, in microsiemens per centimeter at 25 degrees Celsius; TBY, turbidity, in nephelometric turbidity units; --, no data; *E. coli, Escherichia coli*; mL, milliliter]

Site number (table 1; fig.1)	Regression Model	n	R^2	RMSE[1]	Average daily streamflow (ft^3/s)	Median daily streamflow (ft^3/s)	Estimated total load[2] (Mg)	SEP	Estimated average daily yield[2] (kg/km^2)	Estimated annual load[2] (Mg)			Estimated annual flow weighted concentration (mg/L)		
										[3]2006	[3]2007	[3]2008	[3]2006	[3]2007	[3]2008
	Chloride, mg/L														
1	ln(L)=0.663ln(Q)+0.551sin(2πT)+0.884cos(2πT)+0.542	21	0.91	0.590	103	50	1,210	0.238	39.4	205	411	467	106	72.8	54.7
3	ln(L)=0.921ln(Q)+0.226sin(2πT)+0.201cos(2πT)+ 0.0002SC+1.87	24	.99	.174	536	156	16,800	.582	32.6	1,320	6,050	7,380	51.7	46.3	44.8
4	ln(L)=0.634ln(Q)+0.604sin(2πT)+1.15cos(2πT)+ 0.205T+0.338	20	.93	.597	108	31	997	.263	65.3	134	365	482	101	79.5	84.3
5	ln(L)=0.888ln(Q)+0.424sin(2πT)+0.542cos(2πT)+ 0.001SC+0.512	25	.96	.475	108	35	1,960	.310	62.5	197	833	674	74.5	88.2	71.5
6	ln(L)=0.935ln(Q)+0.208sin(2πT)+0.187cos(2πT)+ 0.002SC+2.14	24	.99	.194	841	205	20,700	.834	34.4	1,700	7,300	9,390	46.2	40.5	40.6
	Total Nitrogen, mg/L														
1	ln(L)=1.20ln(Q)+ 0.054ln(Q2)+0.313sin(2πT)- 0.162cos(2πT)-2.82	21	.99	.345	103	50	65.6	.007	2.14	3.98	22.4	33.1	2.06	3.97	3.88
3	ln(L)=1.26ln(Q)+ 0.026ln(Q2)+0.255sin(2πT)+ 0.101cos(2πT)+0.0006TBY-0.853	20	.99	.334	596	184	780	.090	1.51	26.2	336	328	1.03	2.57	1.99
4	ln(L)=1.19ln(Q)+ 0.038ln(Q2)+0.276sin(2πT)- 0.064cos(2πT)-2.89	20	.99	.345	108	31	34.5	.003	2.26	2.48	14.7	15.0	1.87	3.21	2.62
5	ln(L)=1.241ln(Q)-3.15	20	.97	.507	135	62	64.4	.007	1.99	5.36	25.4	25.2	2.02	2.69	2.67
6	ln(L)=1.16ln(Q)+ 0.19ln(Q2)+0.246sin(2πT)- 0.036cos(2πT)+0.002TBY-0.562	21	.99	.278	973	344	1,231	.131	1.98	41.3	574	508	1.12	3.19	2.20
	Total Phosphorus, mg/L														
1	ln(L)=1.41ln(Q)+ 0.058ln(Q2)-0.116T-+0.176sin(2πT)- 0.186cos(2πT)-4.66	20	.99	.333	103	50	15.5	.002	.507	0.723	5.14	8.00	0.37	0.91	0.94
3	ln(L)=1.44ln(Q)+ 0.049ln(Q2)+0.0009TBY-2.70	20	.97	.510	596	184	207	.051	0.399	4.12	96	80.7	0.16	0.73	0.49
4	ln(L)=1.46ln(Q)+ 0.063ln(Q2)-4.80	20	.98	.498	108	31	8.53	.001	.559	.357	3.63	3.91	0.27	0.79	0.68
5	ln(L)=1.35ln(Q)-4.64	20	.93	.899	135	62	22.7	.006	0.702	1.70	9.17	9.07	0.64	0.97	0.96
6	ln(L)=1.38ln(Q)+ 0.034ln(Q2)+0.002TBY-2.35	21	.99	.364	973	344	441	.083	0.710	7.68	230	168	0.21	1.27	0.73
	Suspended Sediment, mg/L														
1	Insufficient data	19	--	--	--	--	--	--	--	--	--	--	--	--	--
3	ln(L)=1.75ln(Q)+ 0.092ln(Q2)-0.213T+3.87	21	.97	.580	615	210	312,000	122	602	2,650	201,000	73,000	104	1,539	443
4	Insufficient data	18	--	--	--	--	--	--	--	--	--	--	--	--	--
5	ln(L)=1.64ln(Q)+0.246sin(2πT)-0.729cos(2πT)+1.61	20	.97	.768	117	54	35,600	11.1	1,100	1,760	16,100	15,100	666	1,706	1,608
6	ln(L)=4.49+1.89ln(Q)+ 0.092ln(Q2)-0.318T+4.49	20	.97	.621	1,000	266	1,080,000	453	1,680	6,310	658,000	215,000	171	3,651	932

Table 10. Regression models for estimating concentrations, densities, and calculated annual loads of selected constituents.—Continued

[n, number of samples; R^2, coefficient of determination; RMSE, root mean squared error; ft^3/s, cubic feet per second; Mg, megagram (metric ton); SEP, standard error of prediction; kg/km^2, kilograms per square kilometer; mg/L, milligrams per liter; ln, natural logarithm; L, instantaneous (daily) load; ln(Q), ln(streamflow) minus center ln(streamflow); ln(Q^2), ln of streamflow squared; sin, sine; T, decimal time minus center of decimal time; cos, cosine; SC, specific conductance, in microsiemens per centimeter at 25 degrees Celsius; TBY, turbidity, in nephelometric turbidity units; --, no data; *E. coli, Escherichia coli*; mL, milliliter]

Site number (table 1; fig.1)	Regression Model	n	R^2	RMSE[1]	Average daily streamflow (ft^3/s)	Median daily streamflow (ft^3/s)	Estimated total load[2] (Mg)	SEP	Estimated average daily yield[2] (kg/km^2)	Estimated annual load[2] (Mg)			Estimated annual flow weighted concentration (mg/L)		
										[3]2006	[3]2007	[3]2008	[3]2006	[3]2007	[3]2008
	E. coli, colonies per 100 mL[4]														
1	$\ln(L)=1.89\ln(Q)-0.223\sin(2\pi T)-1.42\cos(2\pi T)+14.0$	20	0.96	0.816	105	53	12,500,000	6,650	407	315,000	2,270,000	8,790,000	16,300	40,200	[5]103,000
3	$\ln(L)=2.01\ln(Q)-0.521\sin(2\pi T)+0.083\cos(2\pi T)+0.009TBY+15.5$	20	.95	.886	635	219	40,600,000	22,700	78	294,000	18,100,000	15,400,000	1,160	13,900	9,330
4	Insufficient data	18	--	--	--	--	--	--	--	--	--	--	--	--	--
5	$\ln(L)=1.29\ln(Q)-0.384\sin(2\pi T)-0.990\cos(2\pi T)+0.004TBY+12.4$	20	.92	1.23	139	70	33,400,000	2,630	1,080	321,000	1,260,000	1,480,000	12,100	13,300	15,700
6	$\ln(L)=1.94\ln(Q)-0.559\sin(2\pi T)-0.224\cos(2\pi T)+0.002TBY+15.8$	20	.95	.930	1,000	266	92,700,000	53,300	149	889,000	41,800,000	40,800,000	2,410	23,200	17,600

[1]RMSE is calculated from the estimated residual variance for the model.

[2]Estimated *E. coli* loads and yields are in billions of colonies.

[3]Water year, October 1 through September 30.

[4]For the purposes of this report, colonies per 100 milliliters is considered to be comparable to most probable number per 100 milliliters.

[5]Approximately 73 percent of the estimated annual load occurred on one day, July 30. The estimated density was 458,000 colonies per 100 milliliters.

The Missouri chronic standard for AQL for chloride is 230 mg/L and the acute standard is 860 mg/L (Missouri Department of Natural Resources, 2005–2009). Estimated chloride concentrations exceeded the acute standard for only one site, Spring Branch Creek (site 5), during the winter in 2007 and 2008. Estimated concentrations exceeded the acute standard about one percent of the time for site 5 (fig. 23). The chronic standard at all sites was estimated to be exceeded more frequently during the winter and early spring (fig. 22), between about 2 and 30 percent of the time (fig. 23).

The sites that do not have specific conductance included in their chloride regression equations, Rock Creek (site 1) and Crackerneck Creek (site 4; table 10), show a greater percentage exceedance of the chronic standard (fig. 23) than the sites with specific conductance included in the equation. The Rock Creek and Crackerneck Creek basins have a greater percentage of developed land (fig. 3) classified in the low to high intensity categories (65.3 and 62.2 percent) than the Spring Branch Creek Basin (35.4 percent). Sites 1 and 4 also may have had larger chloride concentrations not captured in the model data that continuous monitoring of specific conductance may have detected.

The estimated average daily chloride loads at the sample sites by month and year are shown in figure 24. The median monthly chloride loads for all sites were smaller during early and late summer, July through September, than for the rest of the year. However, the median monthly loads for the Little Blue River sites 3 and 6 remained large for a longer period into the wet season, through May, than for the smaller streams draining Independence that showed large monthly chloride loads through March. The streams draining Independence have a larger percentage of developed land (Rock Creek, 65.3 percent; Crackerneck Creek, 62.2 percent; and Spring Branch Creek, 35.4 percent; fig. 3) with about twice the estimated average chloride yields (table 10) than the Little Blue River upstream from site 3 (28.4 percent; fig. 3). During this study streamflow from Crackerneck Creek and Spring Branch Creek added about 76 percent of the estimated increase in chloride load between sites on the Little Blue River. The effects of de-icers on water quality and stream health during base flow throughout the year in streams in Independence (sites 1, 4, and 5) and their tributaries are not known, but the modeled data indicate a larger effect on the smaller and more urban streams (fig. 23) than for the Little Blue River.

Most metals in stormflow are transported adsorbed to suspended sediment so that concentrations of total recoverable metals in stormflow samples (table 8) are positively correlated with suspended sediment concentrations (fig. 25). Total aluminum had the largest median concentrations in stormflow samples for all sites (3,160 to 11,400 µg/L) and was at least an order of magnitude larger than the combined total of the other metals analyzed (arsenic, cadmium, chromium, copper, lead, mercury, and zinc). Aluminum-enriched clay minerals are abundant in most soils and sediment (Hem, 1992) and are carried to streams in runoff during storms so that as suspended sediment concentrations increase in stormwater so does the

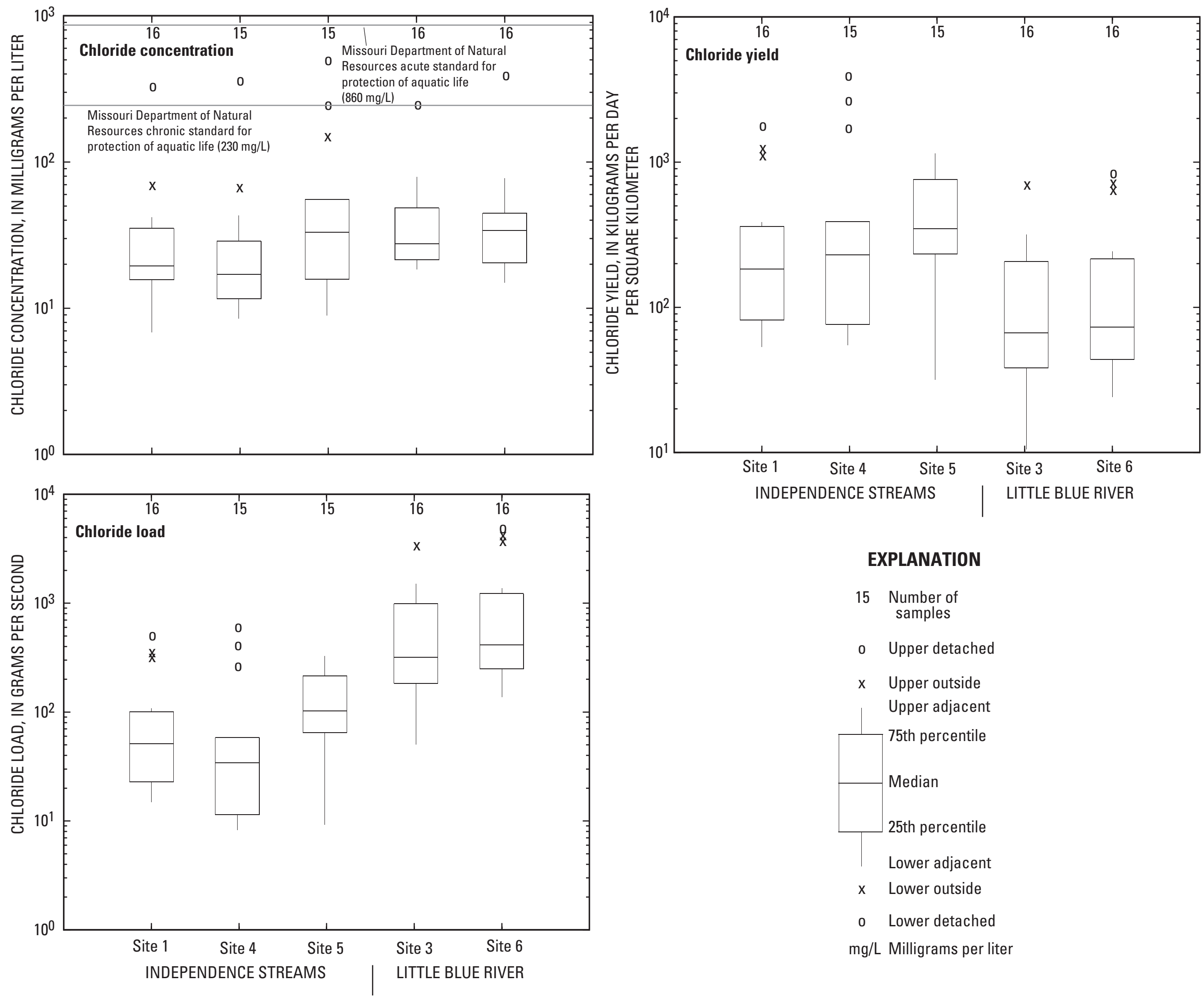


Figure 21. Chloride concentrations, instantaneous loads, and yields in stormflow samples by site, June 2005 through December 2008.

concentration of total recoverable metals (fig. 25). One set of stormflow samples in October 2007 was analyzed for dissolved metals in addition to the total analyses (table 11, at the end of this report) to assess the bioavailability of metals in stormflow. Dissolved metals concentrations in stormflow were small compared to total recoverable metals concentrations. This would be expected because of the small solubility of most metals (Hem, 1992) at the neutral to slightly alkaline pH measured for stormflow samples (tables 8). No dissolved metal concentrations exceeded the chronic or acute standards for AQL (Missouri Department of Natural Resources, 2005–2009). Total recoverable metals, mostly transported during stormflow adsorbed to sediments, had concentrations generally within expected ranges (Hem, 1992; U.S. Geological Survey, 2009a).

Nutrients

Typically, nutrient concentrations in stormflow are attributable to nonpoint sources, but SSOs or CSOs to streams also may contribute substantial quantities of nutrients (Lee and others, 2005; Wilkison and others, 2002, 2006, 2009). Although nutrient concentrations in the streams draining Independence were mostly attributable to nonpoint sources, SSOs have occurred during some storms, in particular in the Rock Creek Basin (U.S. Environmental Protection Agency, 2009). Documented SSOs discharge to Rock Creek downstream from the USGS streamgage and water-quality sampling site (Dorris Bender, City of Independence, written commun., 2009). However, SSOs may contribute to measured nutrient concentrations when Rock Creek is in backwater from the Missouri River or when collection system SSOs occur. The occurrence and magnitude of any such contributions from SSOs to nutrient

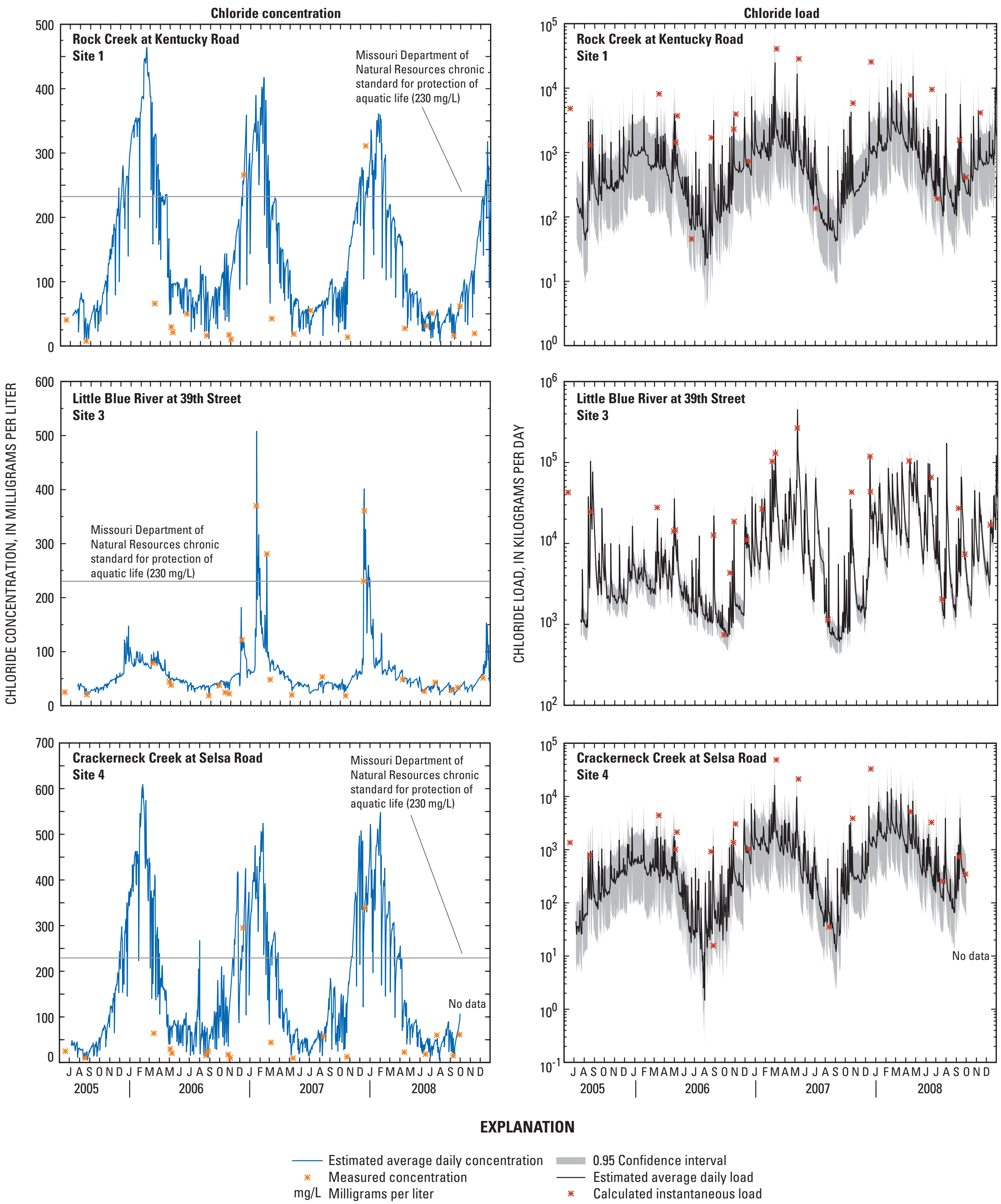


Figure 22. Estimated average daily chloride concentrations and loads by site, July 2005 through December 2008.

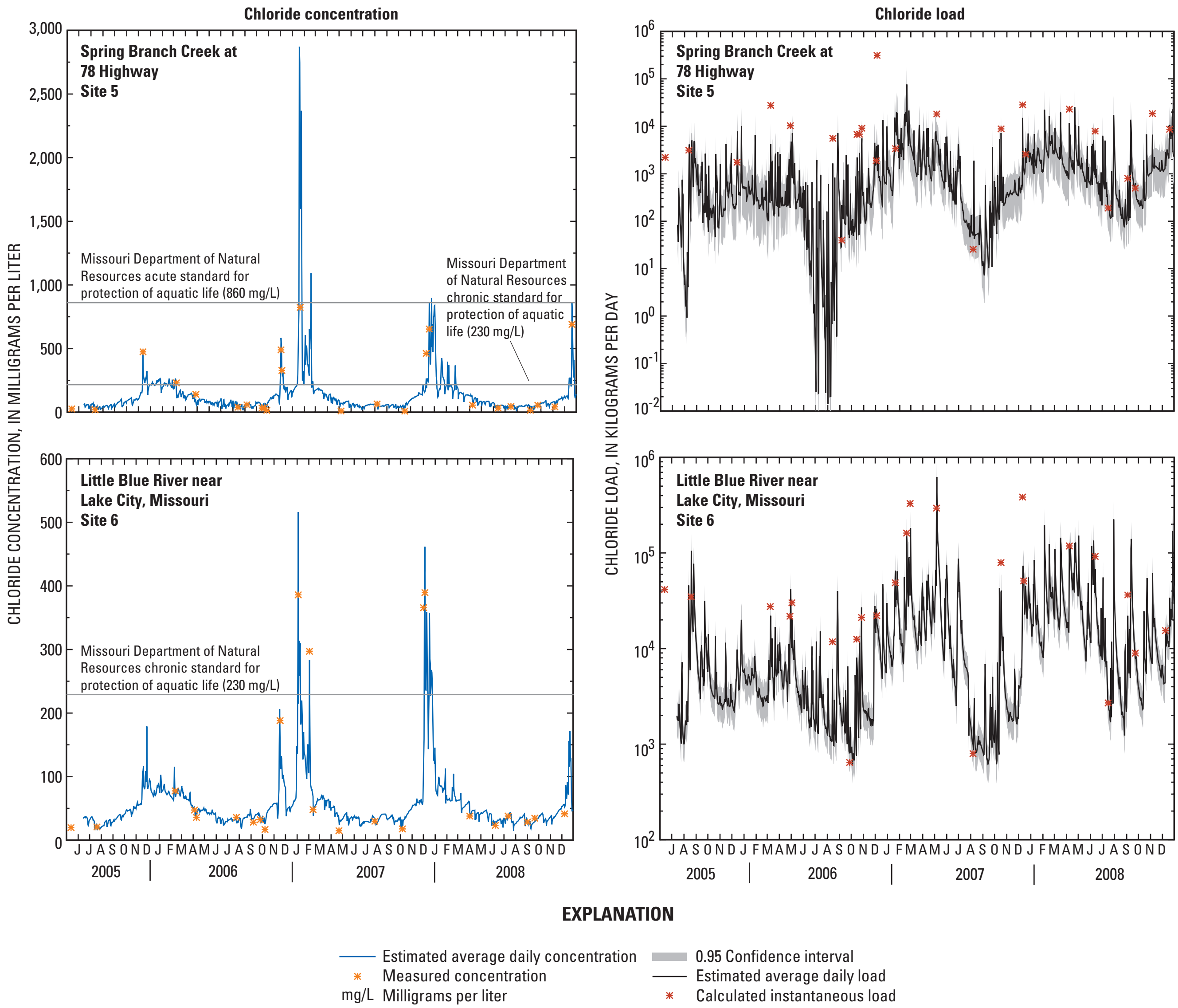


Figure 22. Estimated average daily chloride concentrations and loads by site, July 2005 through December 2008.—Continued

concentrations in Independence streams during stormflow are undocumented, but have been observed by USGS personnel on at least one occasion during this study.

Median total N concentration in stormflow (fig. 26) was largest for Rock Creek (site 1; 3.1 mg/L; table 8), but was not significantly larger than the other sampled streams draining Independence (sites 4 and 5; p=0.72). However, the median total N concentration in stormflow for Rock Creek, Crackerneck Creek, and Spring Branch Creek was significantly larger than for the Little Blue River (sites 3 and 6, p<0.05), most likely because of the settling out of particulate inorganic N in the upstream reservoirs on the Little Blue River. During the study period, average total organic N accounted for between about 76 and 82 percent and NO_3 between about 14 and 19 percent of measured total N concentrations in stormflow (table 8). For all sites, the average total organic N (78 percent) and NO_3 (16 percent) concentrations account for nearly all of the average total N concentration during stormflow.

The median total P concentration during stormflow (fig. 27; table 8) was largest for Spring Branch Creek (site 5; 1.04 mg/L), but concentrations were not significantly different (p=0.64) from the other streams draining Independence. However, they were significantly larger (p<0.05) than the median concentration from Little Blue River site 3 (0.345 mg/L). During base flow, most total P was detected in the dissolved phase. However, during stormflow only about 12 percent of median total P for all sites was dissolved P, most as orthophosphate (table 8). Total P concentrations in stormflow were largely from particulates in suspended sediment (fig. 28).

Median instantaneous loads for nutrients in stormflow increased downstream on the Little Blue River from 14.3 to 30.2 g/s for total N and from 3.35 to 10.1 g/s for total P. The median instantaneous total N and total P yields for stormflow were significantly larger (p<0.05) for Crackerneck Creek and Spring Branch Creek (sites 4 and 5) than loads for the Little Blue River upstream from site 3 (figs. 26 and 27).

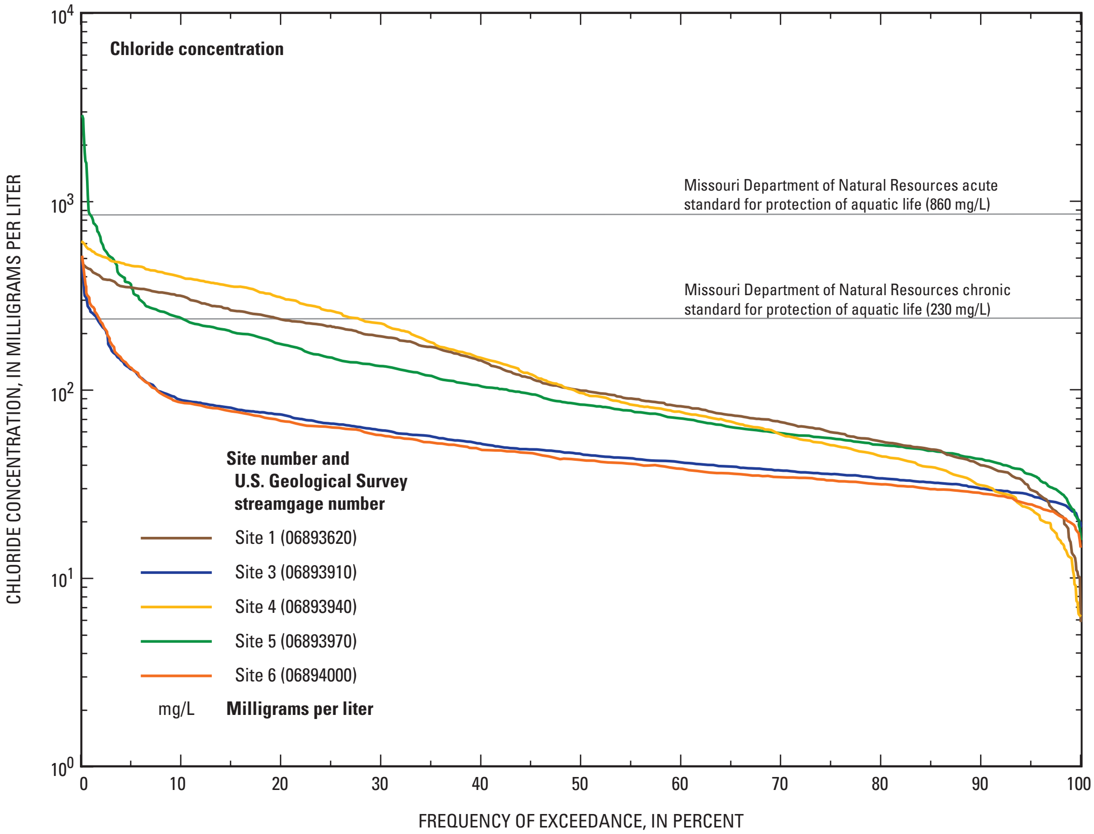


Figure 23. Frequency of exceedance for estimated average daily chloride concentrations by site, July 2005 through December 2008.

Estimated daily total N and P concentrations and loads were calculated with regression equations using measured base-flow and stormflow data for July 2005 through December 2008 (table 10). Turbidity was used as an independent variable for the two Little Blue River sites equipped with CWQMs (sites 3 and 6). The turbidity data for Spring Branch Creek (site 5) were considered to be too incomplete to include in the regression equations because of sedimentation interfering with the sensors during storm recessions before the site was relocated in August 2007. Uncertainties in the regression models for total N were small with high R^2 between 0.97 and 0.99 and low RMSE between 0.278 and 0.507. The R^2 values ranged between 0.93 and 0.99 and RMSE values between 0.333 and 0.899 for total P (table 10).

Clark and others (2000) estimated annual flow-weighted concentrations for total N of 0.26 mg/L and for total P of 0.22 mg/L in streams draining relatively undeveloped basins in the conterminous United States. Similarly, Smith and others (2003) have estimated the natural background concentrations in headwater streams in the southeast temperate forested plains ecoregion, including the study area, to be 0.15 to 0.30 mg/L for total N and 0.06 mg/L or more for total P. However, as noted previously, the average annual precipitation-weighted concentration of dissolved N (NH_4 plus NO_3) is 0.64 mg/L for 2005 through 2008 at five NADP sites surrounding the study area (National Atmospheric Deposition Program/National Trends Network, 2009), which is a substantial contribution to measured concentrations of dissolved N in stormflow. Measured nutrient concentrations greater than these values in stormflow samples likely were attributable to several nonpoint sources that include the transport in runoff of total N and total P from soil, yard and animal waste and other organic matter, and fertilizers from lawns and agricultural fields. Leaky sanitary sewer lines and SSOs also can be a source for nutrients.

Estimated average daily total N concentrations for Rock Creek (site 1) and Crackerneck Creek (site 4), with regression equations that did not include turbidity as a variable, were greater than the EPA recommended guideline of 0.86 mg/L for the entire model period of July 2005 through December 2008 (fig. 29). Spring Branch Creek (site 5), also without turbidity as a variable, exceeded the guideline about 86 percent of the time. The estimated concentrations for the Little Blue River sites exceeded the EPA recommended guideline for total N between 53 and 62 percent of the time. Estimated average daily total P concentrations showed a similar pattern to that of total N (fig. 30). Rock Creek (site 1) and Crackerneck Creek (site 4) had concentrations larger than the recommended guideline for total P concentration of 0.09 mg/L for the entire model period; Spring Branch Creek (site 5) exceeded the recommended guideline about 95 percent of the time; and the Little Blue River sites exceeded the guideline between 81 and 93 percent of the time. The streams draining Independence have a larger percentage of developed land with larger estimated average daily total nutrient yields (table 10) than the Little Blue River upstream from site 3 (fig. 3) so that the estimated total N (about 58 percent) and total P loads (about 113 percent) were larger downstream at site 6 than at upstream

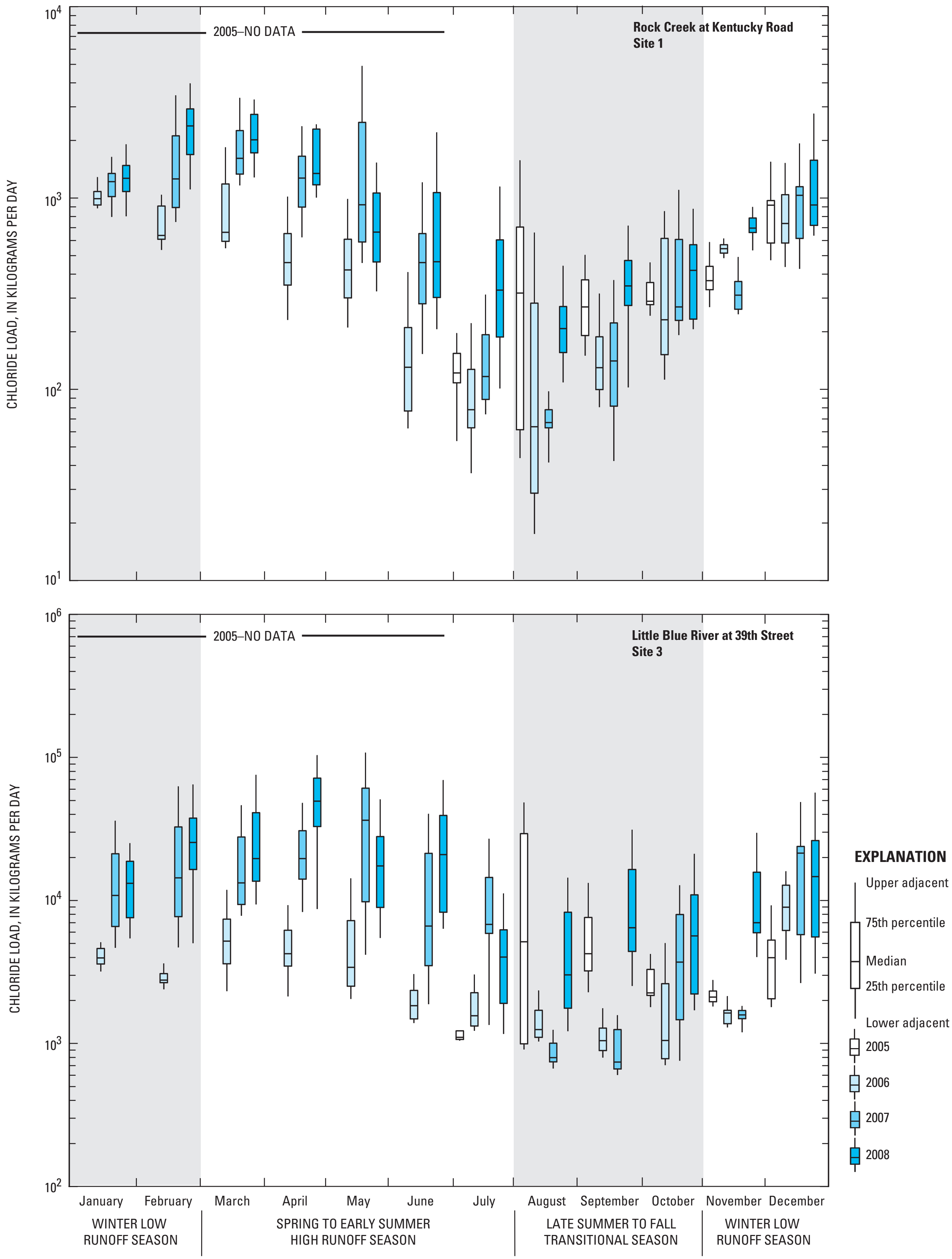


Figure 24. Estimated average daily chloride load by month and year by site, July 2005 through December 2008.

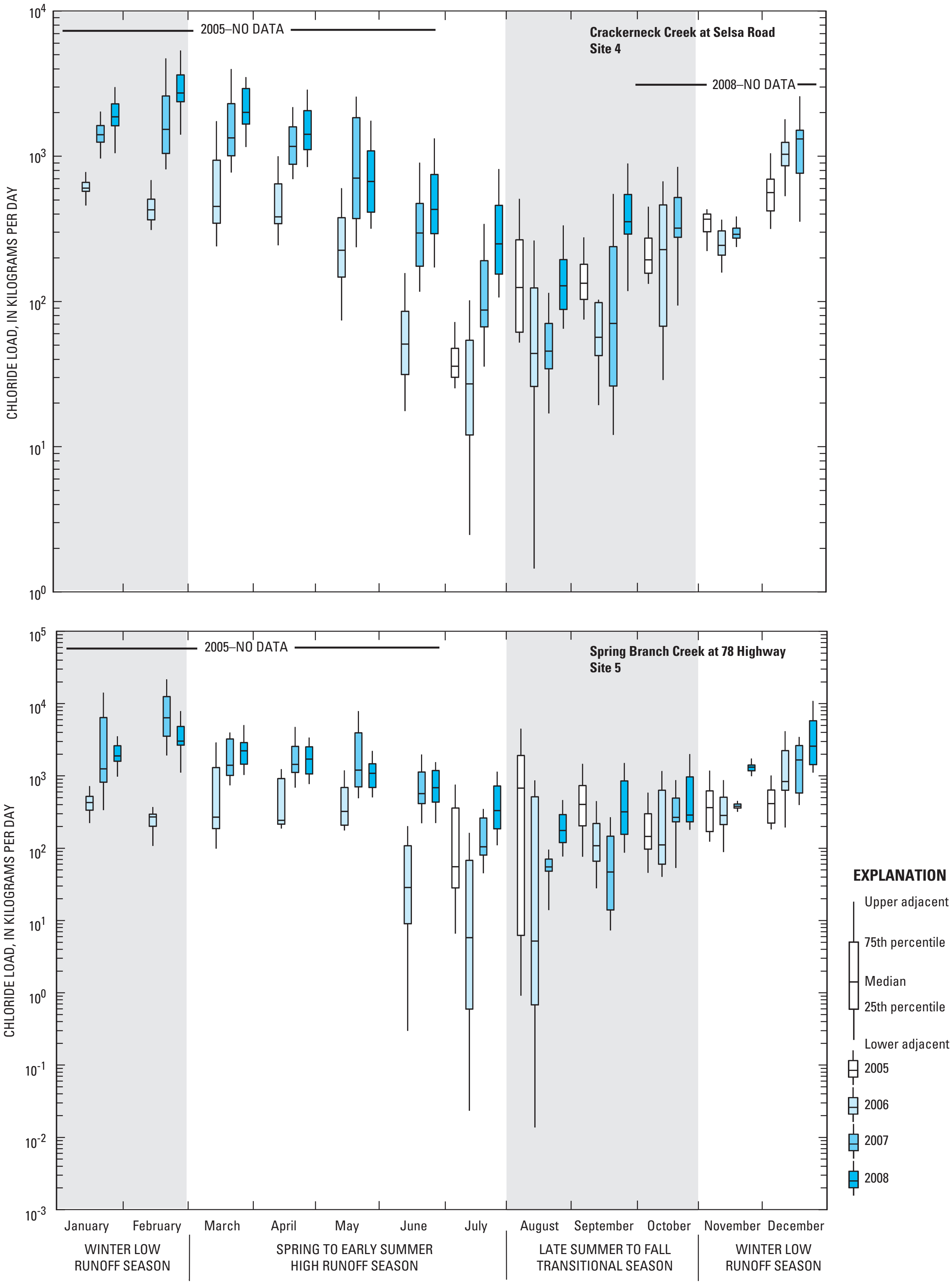


Figure 24. Estimated average daily chloride load by month and year by site, July 2005 through December 2008.—Continued

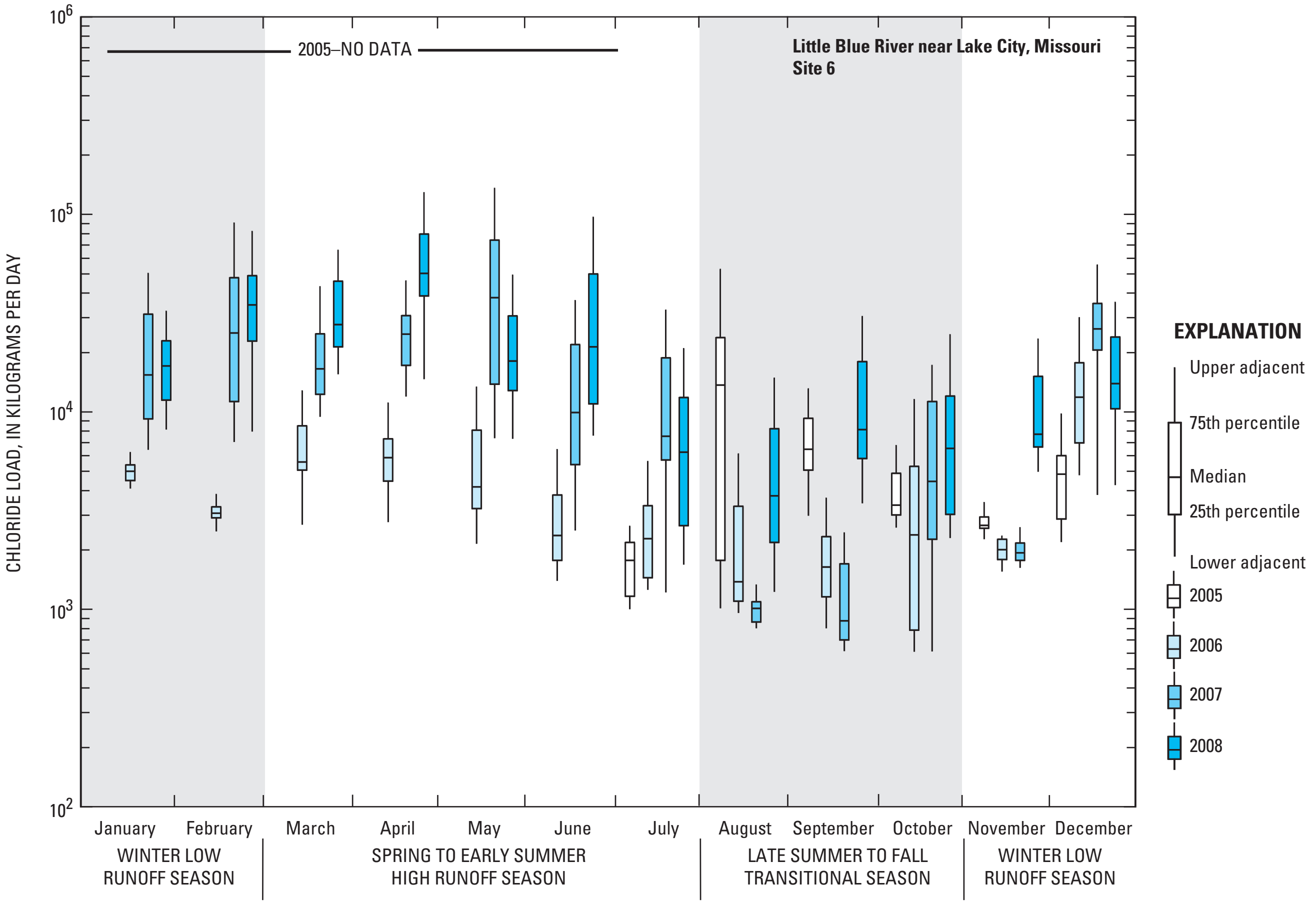


Figure 24. Estimated average daily chloride load by month and year by site, July 2005 through December 2008.—Continued

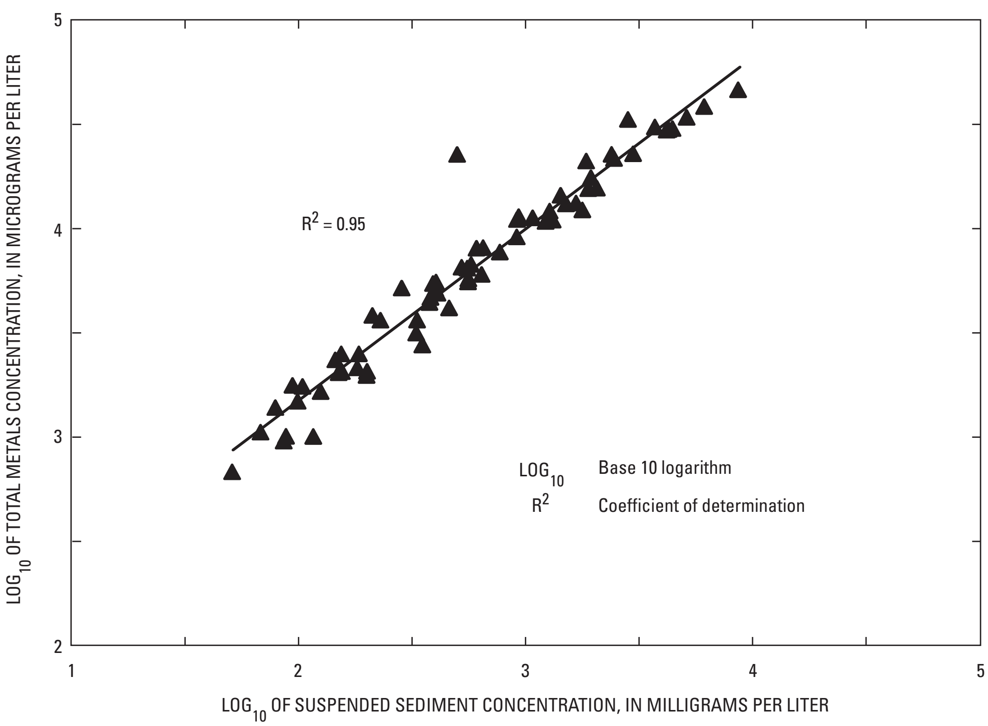


Figure 25. Relation of suspended sediment concentration to the sum of total recoverable metals concentrations.

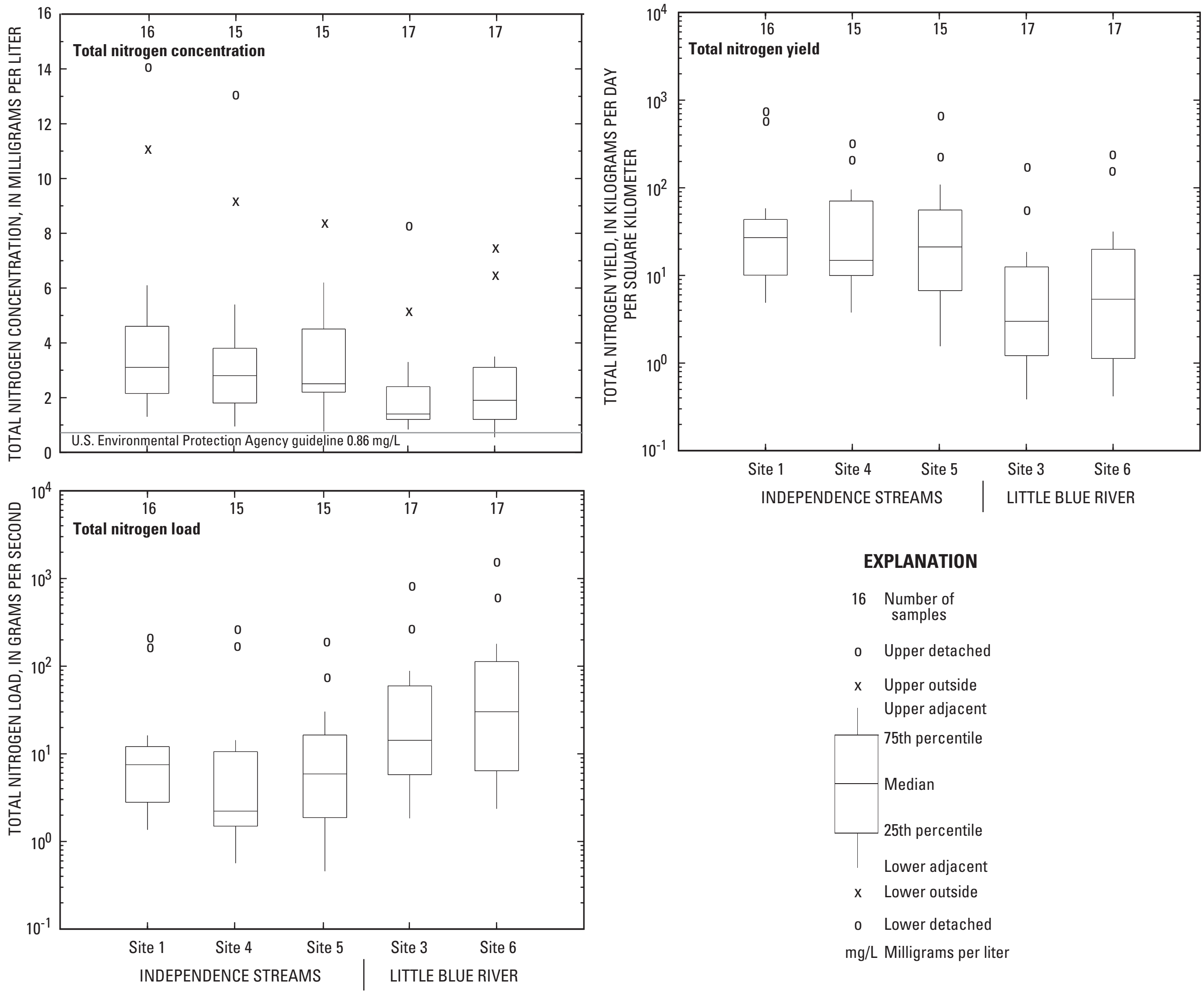


Figure 26. Total nitrogen concentrations and calculated instantaneous loads and yields in stormflow samples by site, June 2005 through September 2008.

site 3 during this study after receiving stormflow from Independence streams.

The relation between suspended sediment concentration and total N concentration is shown in figure 31. Median organic N concentrations, largely particulate or adsorbed to sediment in stormflow, were about 74 percent of total N (table 8) whereas organic N was only 30 percent of median total N in base flow (table 6).

Precipitation of N associated with particulates both in the lakes upstream and in pools within the Little Blue River likely explains the smaller estimated average daily total N concentrations in the Little Blue River compared to the streams draining Independence (fig. 32). Total P concentration curves were similar (fig. 33). Discharge from the reservoirs with smaller suspended sediment concentrations was 100 percent of total flow for the Little Blue River at site 3 about 8 percent of the time and was greater than 50 percent of flow about 68 percent of the time. However, at larger streamflow, as fine-grained streambed materials are mobilized and sediment in direct runoff increases, the Little Blue River with its larger velocity had some larger estimated nutrient concentrations than the smaller streams at the high end (greater than about 98 percent) of the nutrient duration curves (figs. 32 and 33).

The estimated daily total N and total P loads by month and year are shown by site in figures 34 and 35. The average monthly loads for both constituents at all sites were largest during the spring and early summer wet season. The larger loads were mostly attributable to increased streamflow during the wet season, but also because the largest concentrations of both constituents occurred in March through July (figs. 29 and 30). Crackerneck Creek (site 4) and Spring Branch Creek (site 5) contributed about 22 percent of the increase in estimated total N load and about 13 percent of the increase in estimated total P load between sites on the Little Blue River

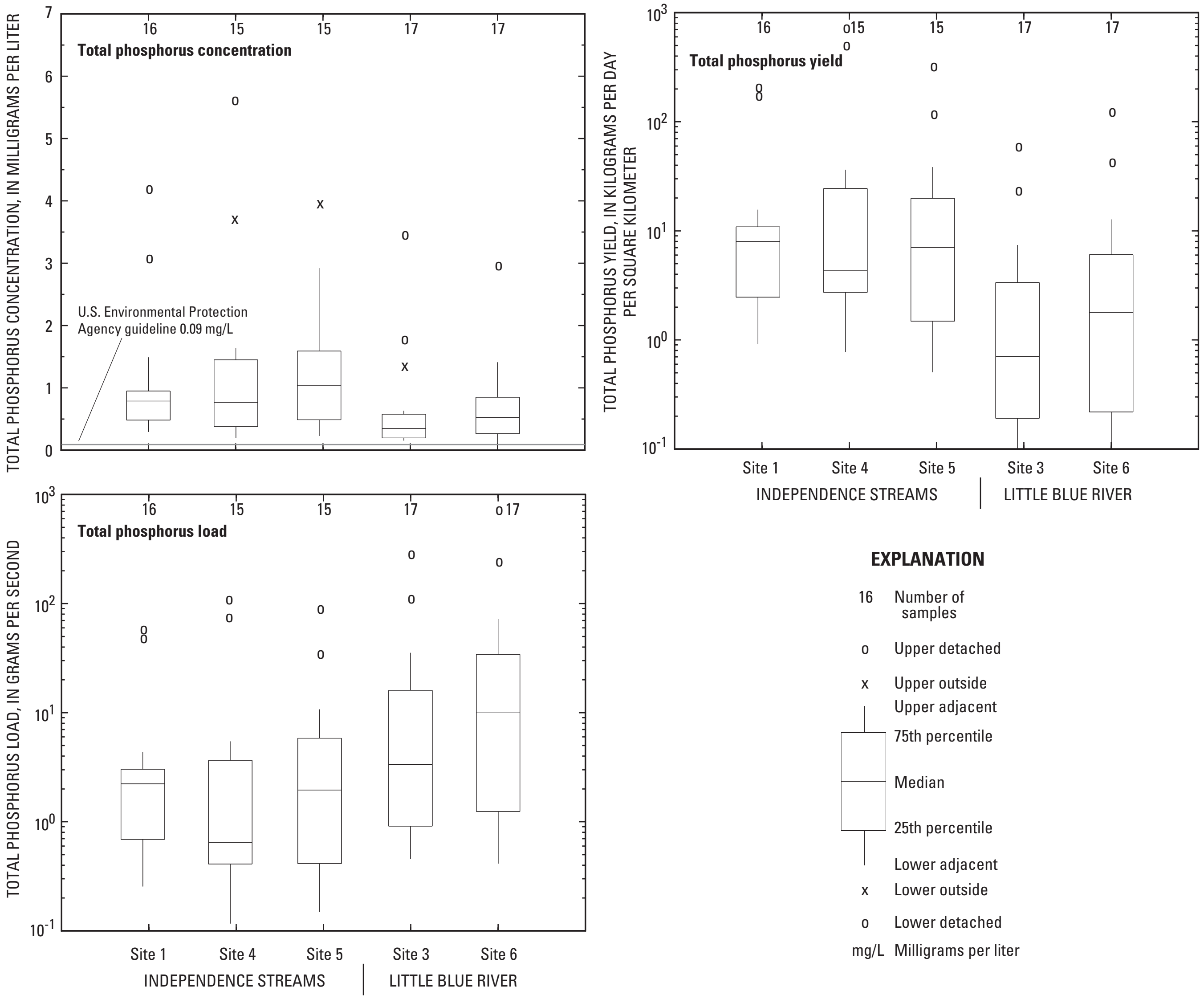


Figure 27. Total phosphorus concentrations and calculated instantaneous loads and yields in stormflow samples by site, June 2005 through September 2008.

during the study period (table 10). Mobilization of organic matter from streambeds and by runoff, along with fertilizer applications to lawns and agricultural fields, likely contributed to the larger concentrations. Contributions of total N from precipitation (table 4) and dry deposition may account for a substantial part of annual loads to streams in the Midwest (Carey and others, 2001), but were not quantified for this report.

Measured suspended sediment concentrations in stormflow between streams were similar, but not significantly different (p=0.06). However, suspended sediment yields in stormflow were significantly larger ($p<0.05$) for the streams draining Independence than yields for the Little Blue River sites (fig. 28) because of the reservoirs trapping suspended sediment from upstream sources. Median suspended sediment loads in stormflow increased downstream on the Little Blue River from 2,150 g/s at site 3 to 9,300 g/s at site 6.

Estimated average daily suspended sediment concentrations and loads were calculated with regression equations (table 10) using measured base-flow and stormflow data for July 2005 through December 2008 for three sites; Spring Branch Creek and the two Little Blue River sites (fig. 36). Insufficient suspended sediment samples were collected at the other two sites to model the data. Turbidity was not used as an independent variable for the Little Blue River sites because the regression equations were not improved over the equations using streamflow, time, and seasonality as variables. The turbidity data for Spring Branch Creek were insufficient to use in the regression equation for that site. Uncertainties in the regression models were small with high R^2 of 0.97 for all sites and low RMSE between 0.580 and 0.768.

Variability existed in calculated annual loads and yields at the three sites (sites 3, 5, and 6) for which suspended sediment loads were modeled. The estimated average daily

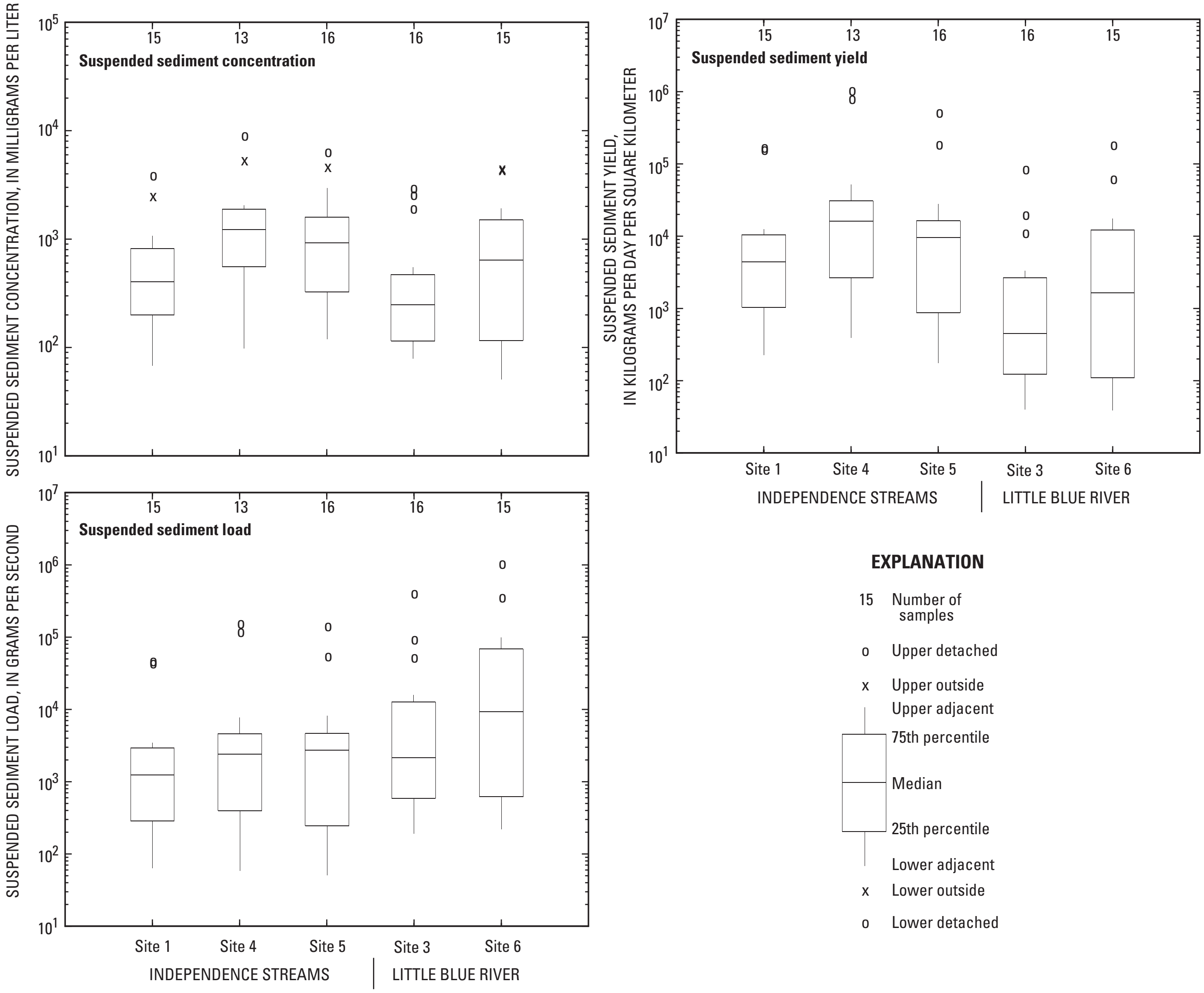


Figure 28. Suspended sediment concentrations and calculated instantaneous loads and yields in stormflow samples by site, August 2005 through September 2008.

suspended sediment yield for the Little Blue River during the study period increased downstream from 602 to 1,680 kilograms per square kilometer (kg/km^2)so that estimated annual suspended sediment loads for the Little Blue River were more than two to more than three times larger downstream at site 6 than upstream at site 3 (table 10) with only about a 20 percent increase in total drainage area. The estimated annual loads for WY 2006, when precipitation was low (fig. 10), were about one to two orders of magnitude less than the loads estimated for WYs 2007 and 2008 for the Little Blue River sites and Spring Branch Creek (site 5). The estimated annual suspended sediment load for the Little Blue River at site 6 in WY 2006 was less than one percent of the 658,000 megagram (Mg) load in WY 2007. Remobilization of sediment stored in pools and on the floodplain of the Little Blue River along with road and commercial construction activities in the lower portions of the Crackerneck Creek and Spring Branch Creek basins and along the Little Blue River are likely contributors to the larger loads downstream for the Little Blue River at site 6 for all 3 years. The monthly variation in suspended sediment loads by site is shown in figure 37, with the increase in sediment loads during the spring to early summer wet season for the Little Blue River sites, although in WY 2006 when conditions were dry the increase was less than in WYs 2007 and 2008.

For all constituents analyzed, loads, but not necessarily concentrations, increased downstream in the Little Blue River. Two streams draining Independence, Crackerneck Creek and Spring Branch Creek, contributed about 76 percent of the increase between sites on the Little Blue River in estimated chloride load, about 22 percent of the increase in total N load, and about 13 percent of the increase in total P load during the study period (table 10). Larger relative percentage contributions occurred during lower flows in WY 2006. Rock Creek had smaller flow-weighted concentrations for chloride than

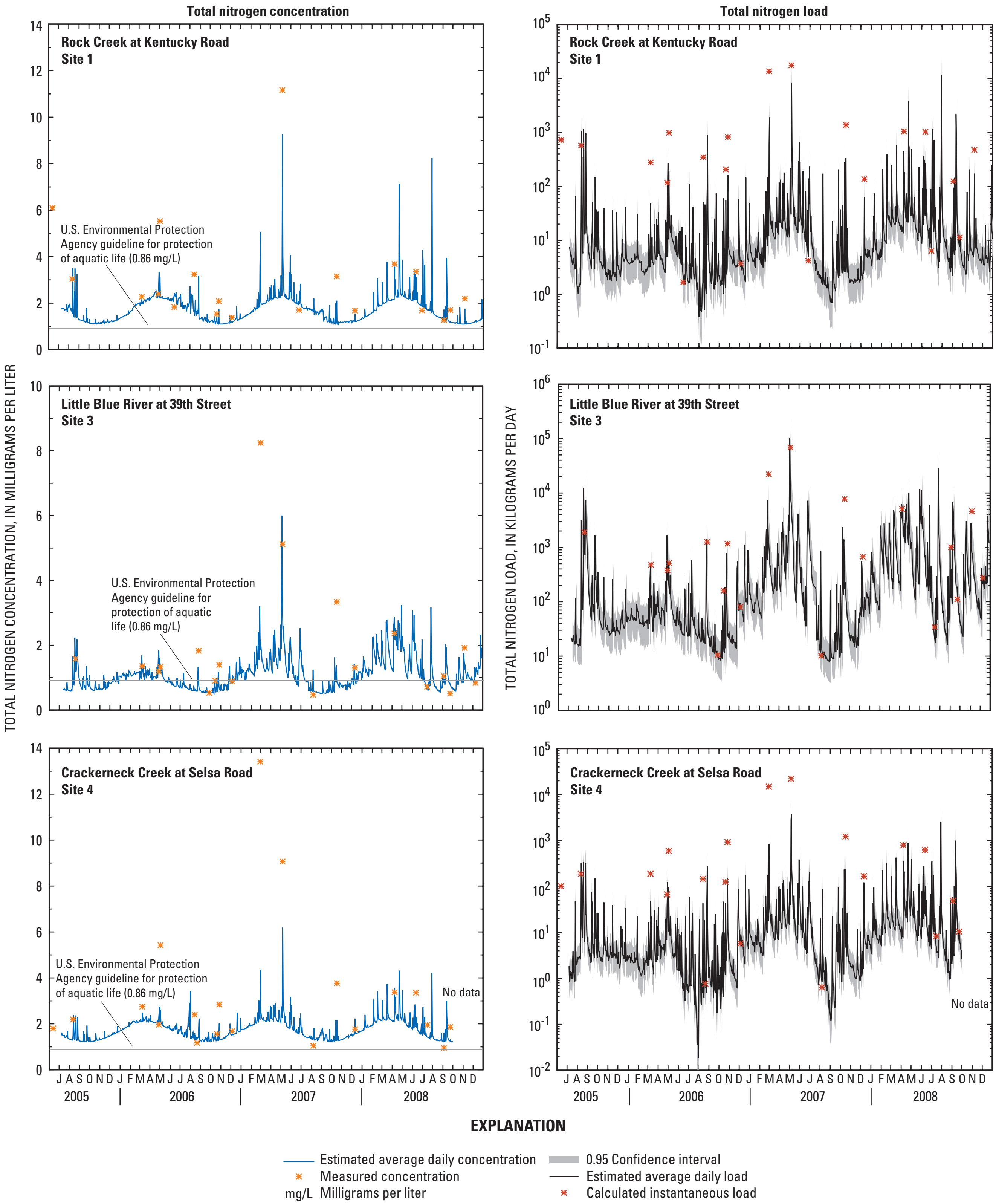


Figure 29. Estimated average daily total nitrogen concentrations and loads by site, July 2005 through December 2008.

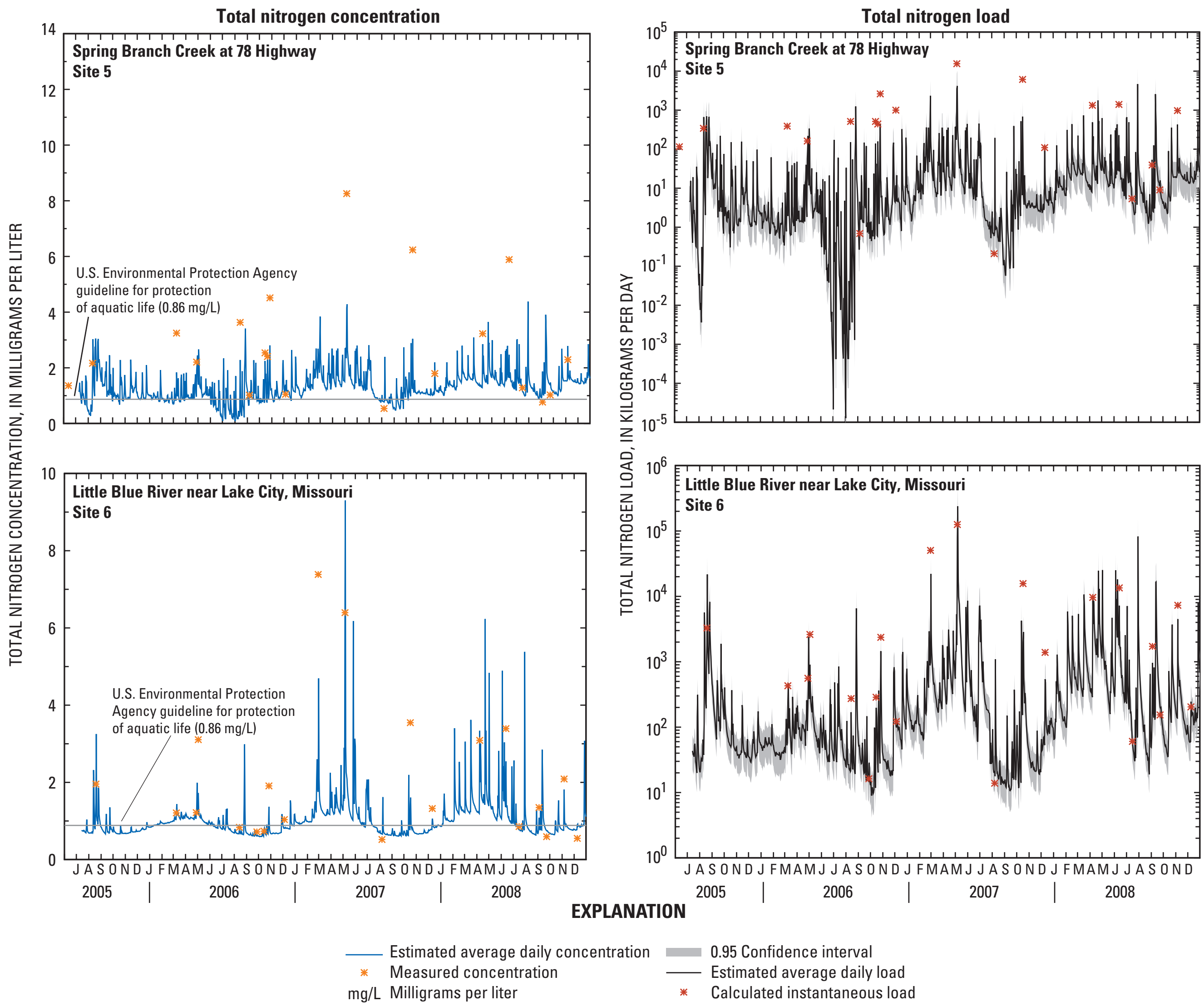


Figure 29. Estimated average daily total nitrogen concentrations and loads by site, July 2005 through December 2008.—Continued

the other two streams draining Independence in WYs 2007 and 2008, but the concentrations were larger in WY 2006 when conditions were dry. Rock Creek also had larger flow-weighted annual concentrations of total N, but only marginally, in WY 2006 and its annual flow-weighted concentrations for total P were intermediate between the two other sites.

Common Organic Micro-Constituents

A total of 76 stormflow samples collected between June 2005 and December 2008 were analyzed for OMCs (table 9). Stormflow samples had a larger median concentration of OMCs (6.82 µg/L; table 9) than base-flow samples (1.77 µg/L; table 7). The four categories with the most total detections had samples with detections more than 90 percent of the time; pesticides (100 percent), PAHs and combustion by-products (99 percent), plastics (93 percent), and stimulants (91 percent). Most detections were small and many were less than 2 µg/L or the NWQL LRL of the constituent and not quantified (data on file at the USGS Water Science Center office in Lee's Summit). The most frequently detected compounds were pesticides; 9,10-anthraquinone (96 percent), DEET (92 percent), and carbazole (89 percent); the PAHs and combustion by-products; fluoranthene (93 percent), pyrene (92 percent), and phenanthrene (91 percent); and the stimulant, caffeine (91 percent). However, the pesticide 3,4-dichlorophenyl isocyanate had a larger median concentration (1.10 µg/L) than the most frequently detected compounds and was detected in 78 percent of the samples. The detergent diethoxy-nonylphenol (all isomers) had the largest overall median concentration of 1.36 µg/L and was detected in 32 percent of samples. Concentrations of OMCs in stormflow samples are summarized by category in table 9. Rock Creek (site 1) had the largest median concentration of total OMCs in stormflow, 15.6 µg/L,

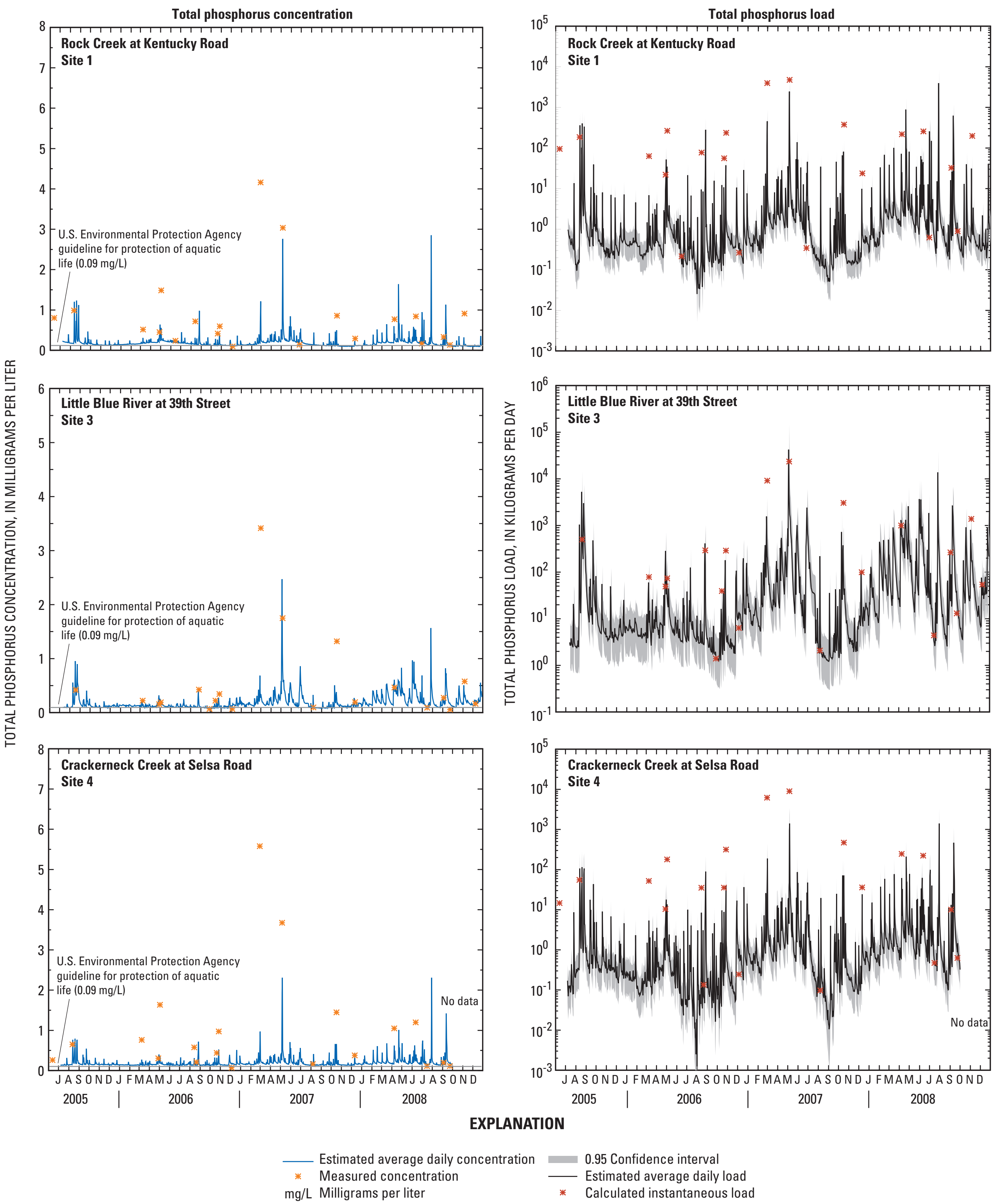


Figure 30. Estimated average daily total phosphorus concentrations and loads by site, July 2005 through December 2008.

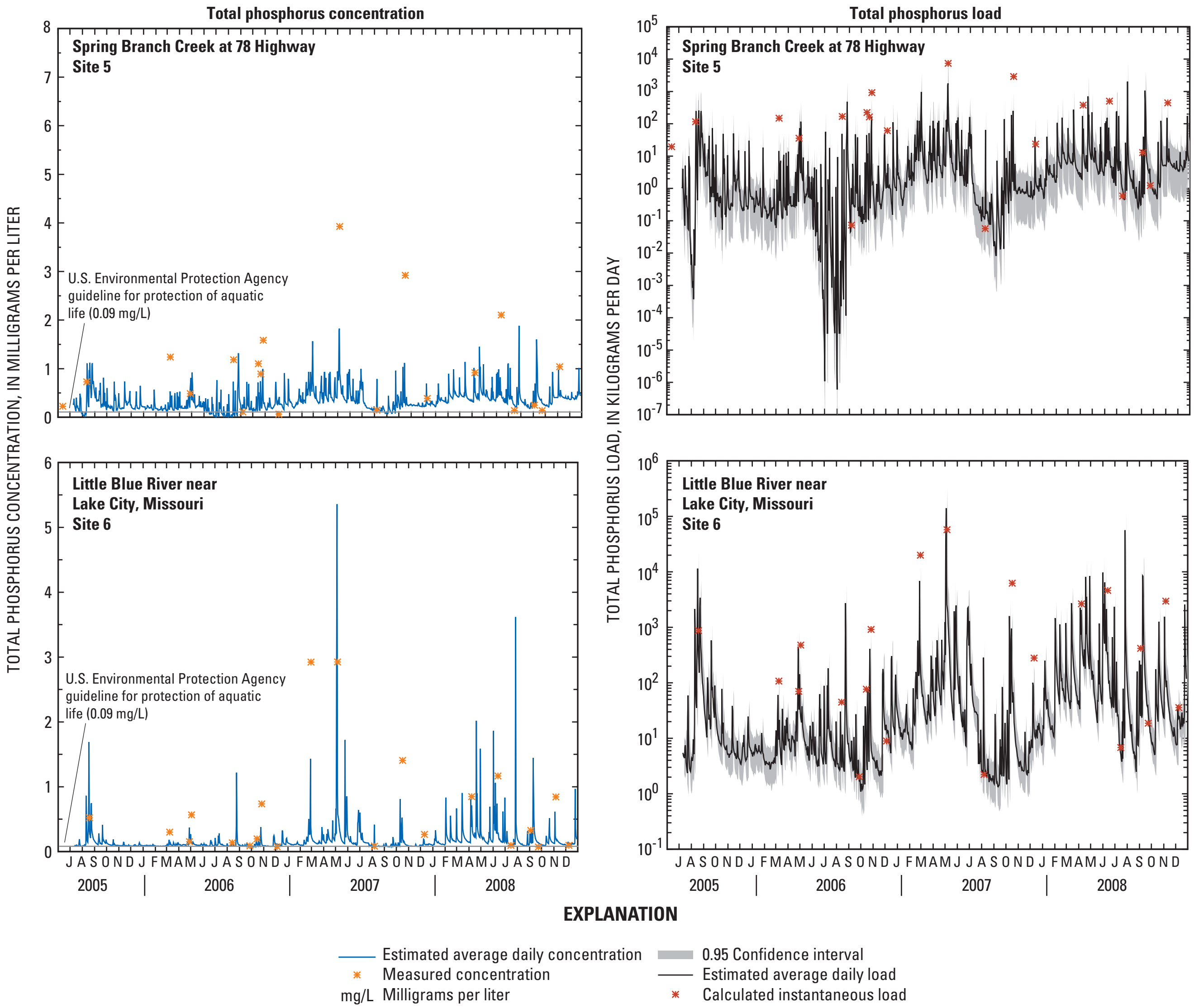


Figure 30. Estimated average daily total phosphorus concentrations and loads by site, July 2005 through December 2008.—Continued

followed by Crackerneck Creek (site 4) with 10.5 µg/L, and Spring Branch Creek (site 5) with 7.86 µg/L. Larger concentrations for Rock Creek are likely attributable to contributions from SSOs. The OMC concentrations in stormflow for the Little Blue River sites were smaller (table 9). The contribution of OMCs by Crackerneck Creek and Spring Branch Creek did not increase concentrations downstream for the Little Blue River. Kolpin and others (2004) stated in a study of differing flow conditions downstream from towns and cities in Iowa that the urban contribution to streams of OMCs decreased as streamflow increased. This study shows similar results, with the median concentration of OMCs slightly larger for the Little Blue River upstream at site 3 (4.95 µg/L) than downstream at site 6 (3.84 µg/L), possibly because of in-stream degradation of OMCs.

Dry-Weather Screening

From 2006 through 2008 dry-weather screening was conducted jointly by the USGS and Independence personnel in all basins within the city limits of Independence except for Fire Prairie Creek and West Fire Prairie Creek (table 1, fig. 2). All visible discharges, inflows, or tributaries of the selected stream were sampled. Eight basins were screened. Two basins were screened multiple times; Rock Creek in all 3 years and Adair Creek in 2007 and 2008 (table 12, at the end of this report). A total of 536 samples were collected during dry-weather screening for analysis of total chlorine, total dissolved copper, phenols, and anionic surfactants. Sample locations and detections of measured constituents are identified on each of the basin maps in figure 38. Seventy-five samples (14.0 percent) had measured concentrations exceeding the guideline or standard used for comparison in this study for one or more of three

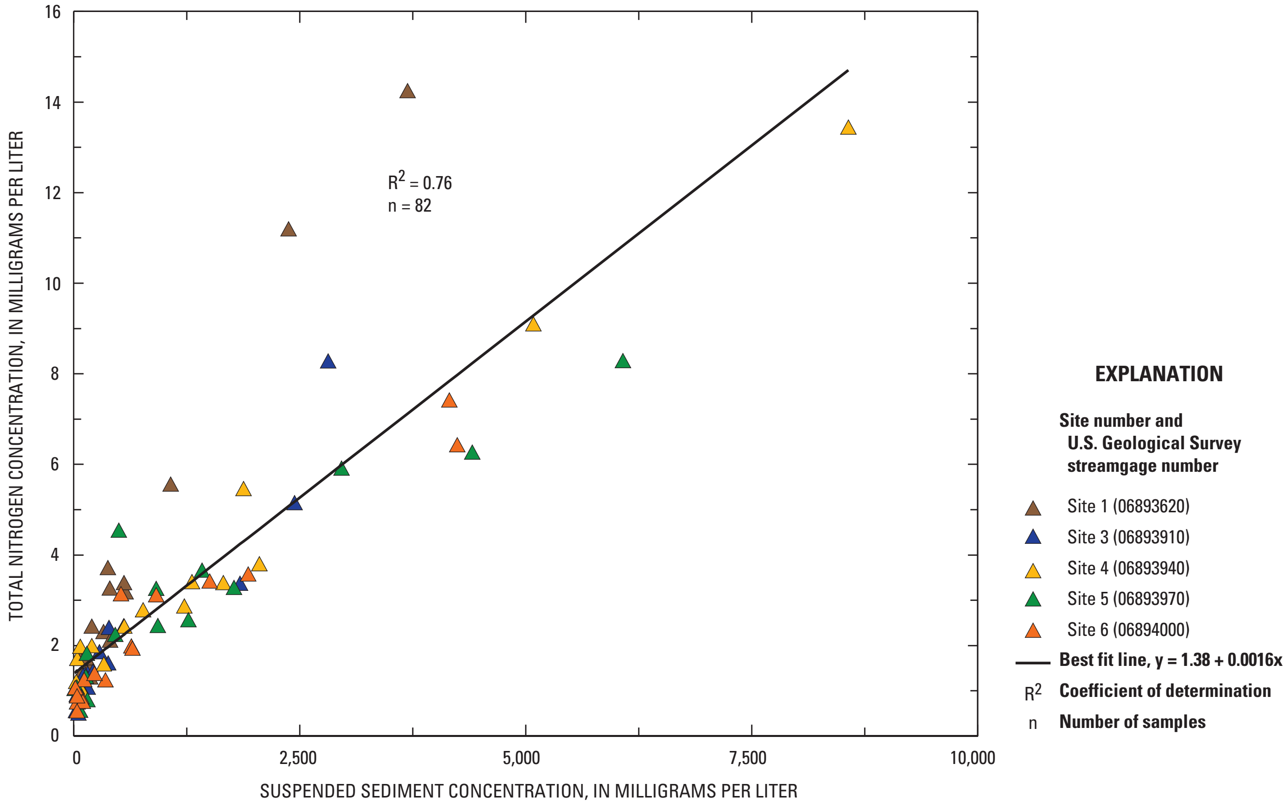


Figure 31. Relation between suspended sediment and total nitrogen concentration in stream samples, August 2005 through December 2008.

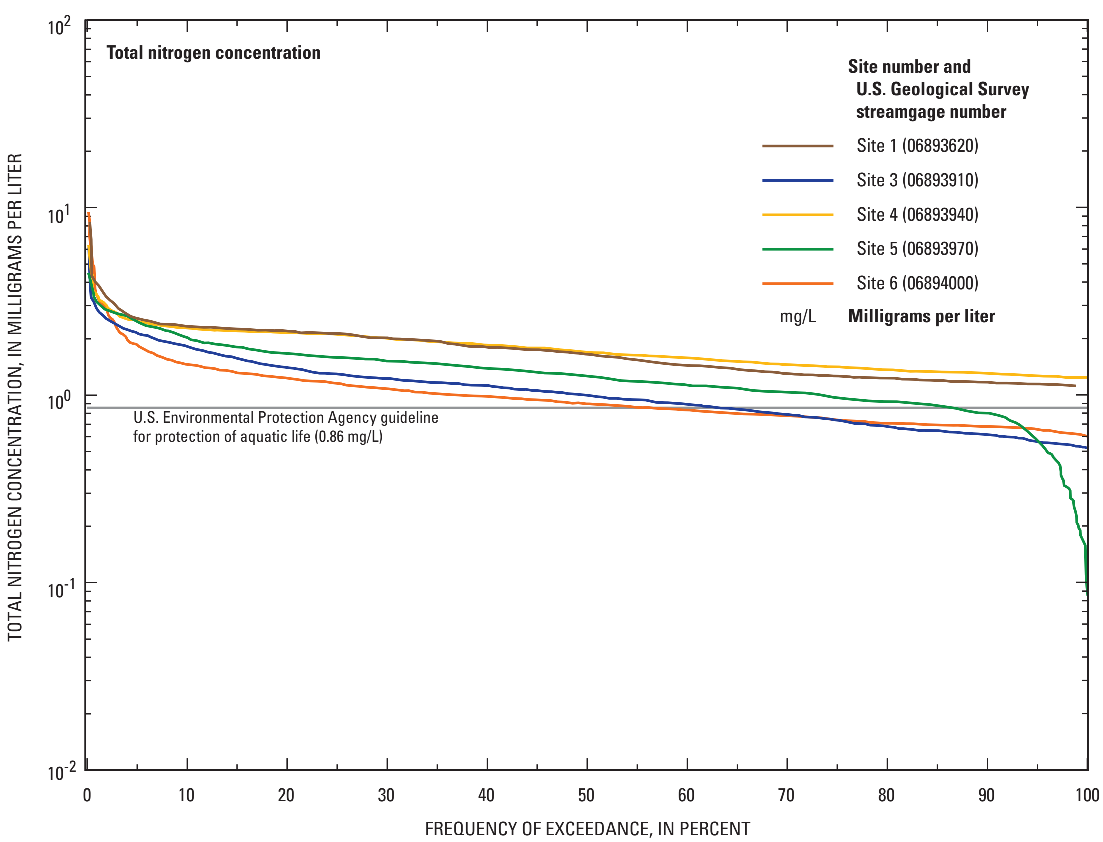


Figure 32. Frequency of exceedance for estimated average daily total nitrogen concentration by site, July 2005 through December 2008.

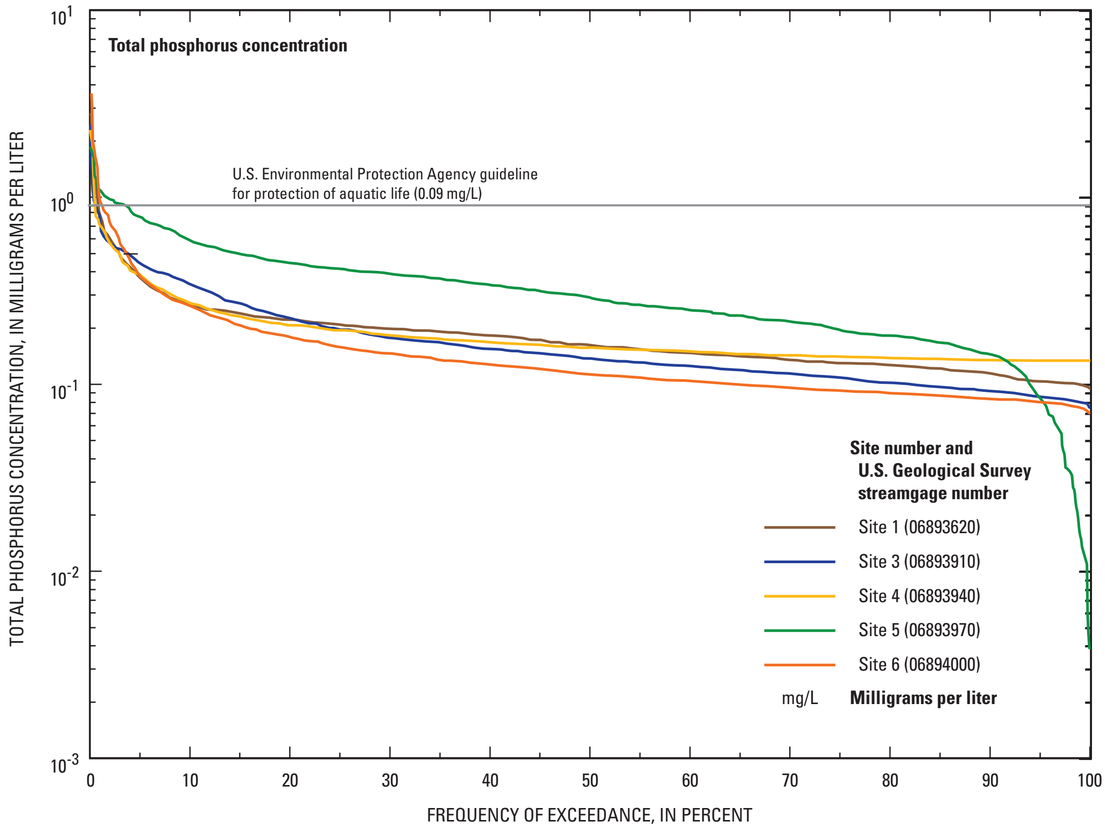


Figure 33. Frequency of exceedance for estimated average daily total phosphorus concentration by site, July 2005 through December 2008.

constituents; total chlorine, phenols, and anionic surfactants. Any discharge that had a measured concentration exceeding a guideline or standard was considered a potential point source of contamination. However, for most detections (65), a source could not be determined and were considered to be episodic (*de minimus*) and most likely attributable to sources such as lawn watering or car washing. Ten samples (1.9 percent) had identifiable point sources.

Boxplots of the dry-weather screening data are shown in figure 39. The EDL and provisional MDL for each analyte are shown on each graph, along with the guideline or standard for those analytes that have one, total chlorine and phenols. A provisional MDL was computed for each analyte because of the variation in the quality-control data at small concentrations (fig. 8) near the EDL. The concentrations less than the EDL on each graph were distributed using the AMLE method in TIBCO Spotfire S+ 8.1 for Windows (The Information Bus Company Software Inc., 2008). A censoring value equal to the provisional MDL for each analyte was then applied to the boxplots below which the concentrations are shown in grey (fig. 39).

Out of 536 samples for total chlorine, there were 495 detections (table 12) exceeding the EDL of 0.02 mg/L. Twenty-seven total chlorine detections were equal to or exceeded the Missouri permitting level of 0.13 mg/L (fig. 39; Missouri Department of Natural Resources, 2006). Six basins had one or more detections of total chlorine equal to or exceeding 0.13 mg/L; Rock Creek, Sugar Creek, Mill Creek, Adair Creek, Crackerneck Creek, and Burr Oak Creek (fig. 38). Rock Creek had six detections (11.1 percent) exceeding the Missouri permitting level in 2006, nine detections (17.3 percent) in 2007, but only a single detection (1.1 percent) in 2008. Sugar Creek had one detection (12.5 percent). Mill Creek had four detections (7.4 percent) and Adair Creek also had four detections (5.3 percent) equal to or exceeding 0.13 mg/L in 2007. Crackerneck Creek and Burr Oak Creek each had one detection (3.2 and 4.5 percent). Two basins did not have any detections; Spring Branch Creek and Bundshu Creek. The largest median total chlorine concentration in dry-weather screening samples was 0.11 mg/L from the Sugar Creek Basin in 2007. All other basins had median total chlorine concentrations of less than or equal to 0.07 mg/L. The median detected concentration of total chlorine in the Rock Creek Basin was less than the provisional MDL of 0.05 mg/L in 2006, 0.07 mg/L in 2007, and equal to the provisional MDL in 2008. Total chlorine detections in the Adair Creek Basin had a median equal to the provisional MDL of 0.05 mg/L in 2007 and less than the provisional MDL in 2008. The larger detections of total chlorine for Adair Creek (fig. 39) all occurred along Interstate 70 (I-70).

Because total chlorine is not commonly detected in untreated water and is unstable in the environment, the main source of total chlorine in streams likely comes from leaky water-supply pipes, lawn watering, irrigation, or illicit discharges. Drinking water from Independence contains about 2.0 mg/L of total chlorine as it leaves the treatment facility (City

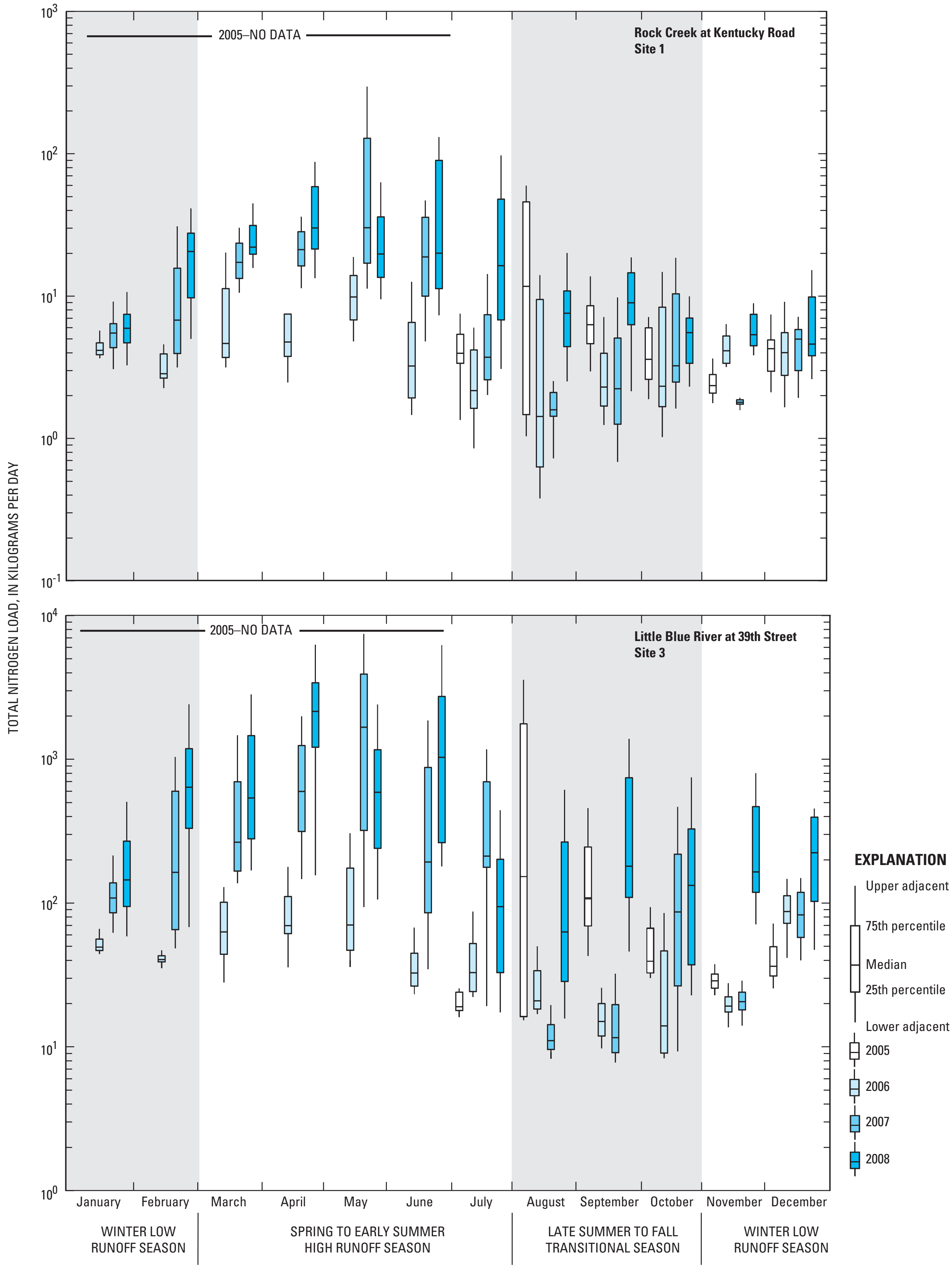


Figure 34. Estimated average daily total nitrogen load by month and year by site, July 2005 through December 2008.

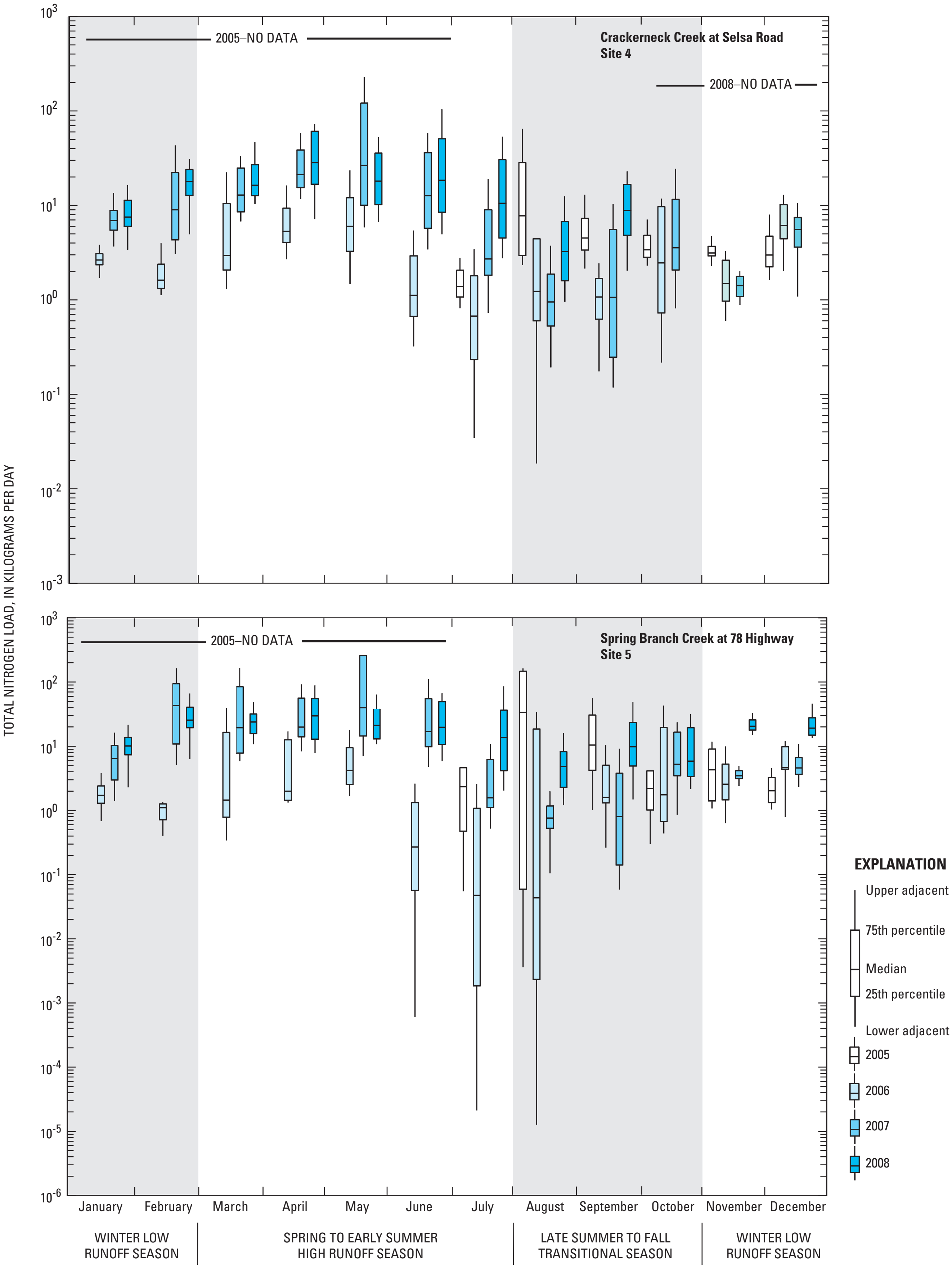


Figure 34. Estimated average daily total nitrogen load by month and year by site, July 2005 through December 2008.—Continued

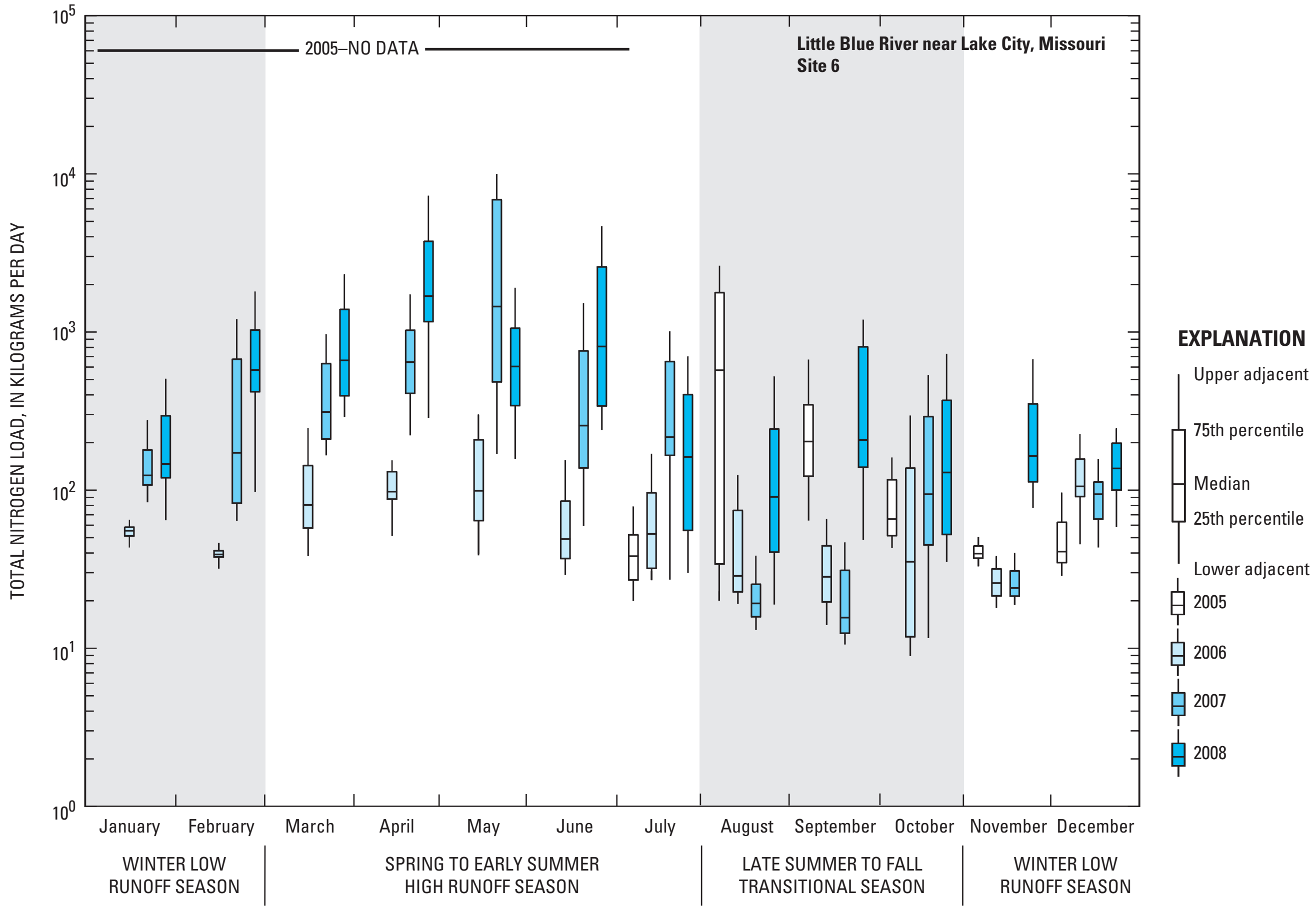


Figure 34. Estimated average daily total nitrogen load by month and year by site, July 2005 through December 2008.—Continued

of Independence, 2009). Therefore, any discharge to streams at low flow from a municipal water-supply source would likely produce detectable chlorine concentrations in the stream. The maximum total chlorine detection was 7.00 mg/L, for a sample from a grey-water pipe discharging from a residence in the Mill Creek Basin in 2007. Dry-weather screening conducted in 1991 and 1992 for total chlorine had 45 detections (20 percent) with a maximum concentration of 0.9 mg/L (Schalk, 1993). However, in that study, the MDL for total chlorine was 0.10 mg/L, which was larger than the provisional MDL for this study (0.05 mg/L). In this study, 57.6 percent of the concentrations of total chlorine were equal to or exceeded the current (2010) provisional MDL, but only 13.4 percent of concentrations were equal to or greater than the MDL used in 1991 and 1992.

Out of 536 samples for total dissolved copper, there were 131 detections (table 12) equal to or exceeding the EDL of 0.04 mg/L and 92 detections equal to or exceeding the provisional MDL of 0.05 mg/L, with a maximum detection of 0.18 mg/L in the central portion of the Rock Creek Basin in 2006. The median concentration for total dissolved copper at all sites was less than the provisional MDL of 0.05 mg/L. The small detections of total dissolved copper exceeding the EDL and at or near the provisional MDL used for dry-weather screening are suspected of being biased high (see Sample Collection and Procedures section). Total dissolved metals samples were not typically collected during base-flow or stormflow sampling for this study. However, total dissolved metals were collected for comparison purposes to total recoverable metals during stormflow on October 17, 2007 (table 11). The largest concentration of total dissolved copper detected during this sampling was 0.002 mg/L. The largest concentration of total recoverable copper detected in 25 base-flow samples collected during this study was about 0.003 mg/L (table 6). Some studies indicate background concentrations of dissolved copper in streams close to 0.01 mg/L (Durfor and Becker, 1964; Turekian, 1969) and larger concentrations may be fairly common (Hem, 1992). The copper concentrations detected during this study are similar to background concentrations presented in those studies and are, therefore, not likely to be a risk to aquatic life in the streams.

The median total dissolved copper concentration detected in dry-weather screening samples was less than the provisional MDL of 0.05 mg/L (fig. 39) for all samples. Standards for AQL are for dissolved copper and are not comparable to the copper analysis method used during dry-weather screening because a valid comparison cannot be made between filtered and unfiltered samples. In this study, 17.2 percent of total dissolved copper samples were equal to or exceeded the provisional MDL, but only 1.1 percent were equal to greater than

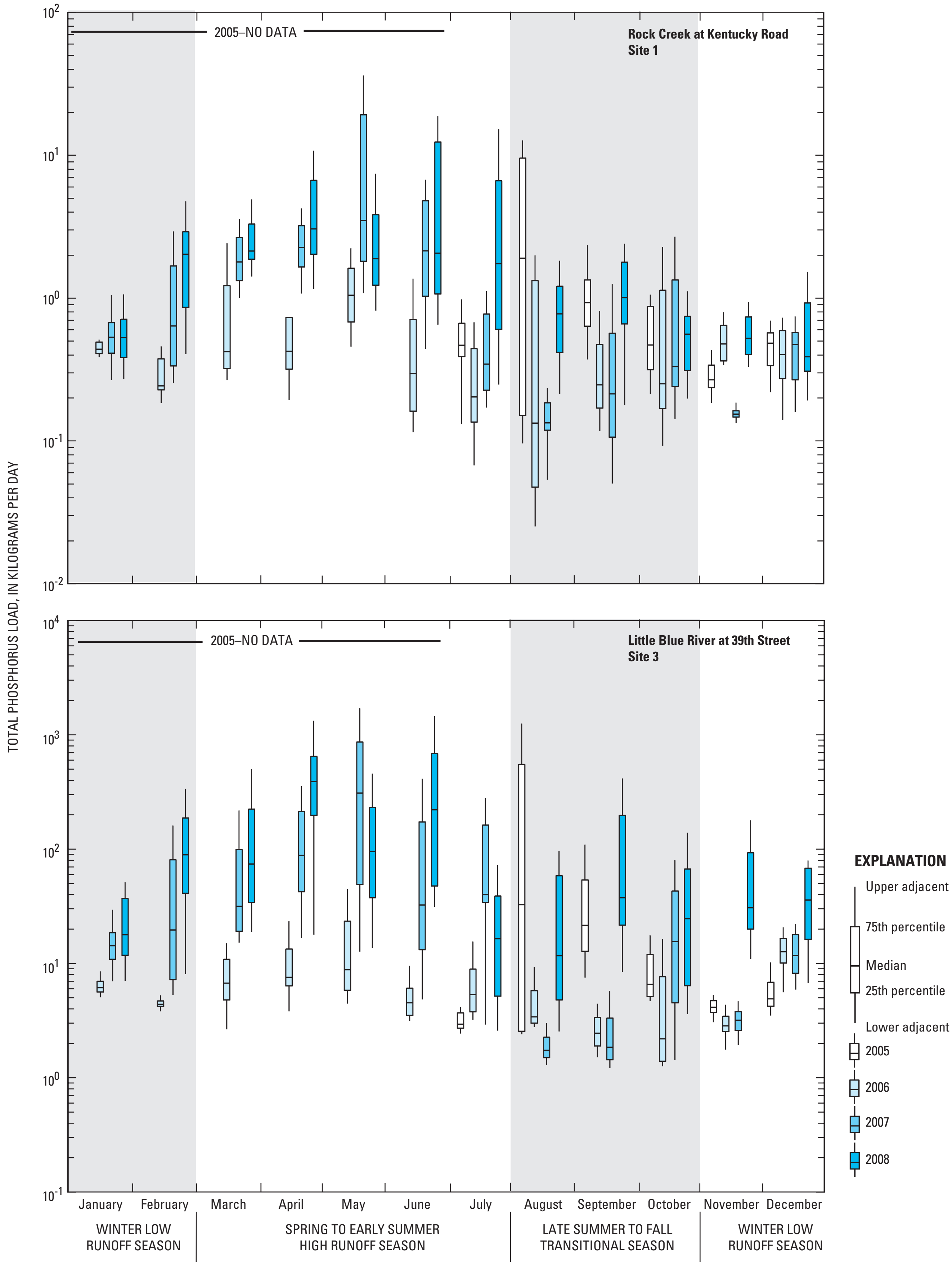


Figure 35. Estimated average daily total phosphorus load by month and year by site, July 2005 through December 2008.

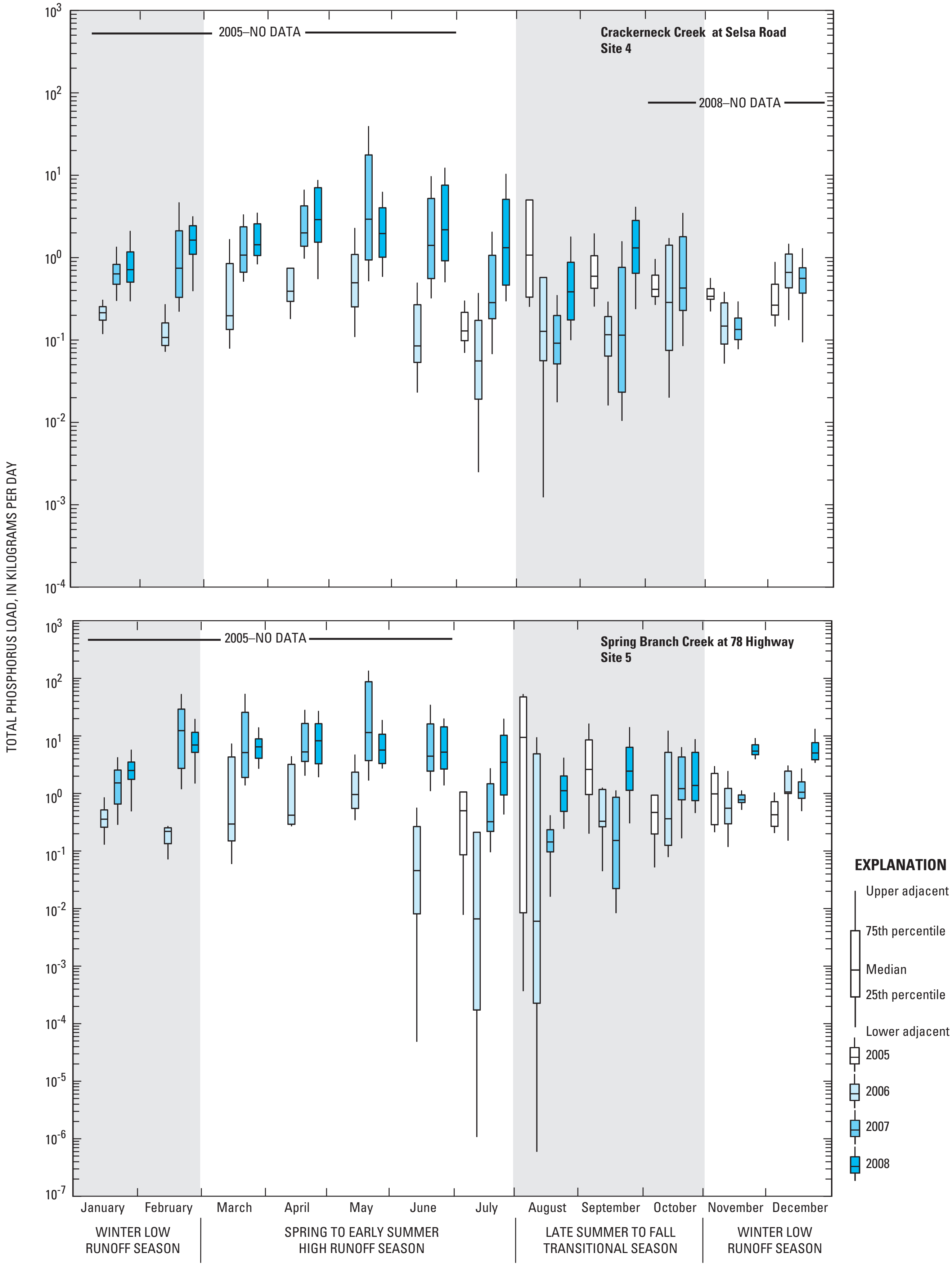


Figure 35. Estimated average daily total phosphorus load by month and year by site, July 2005 through December 2008.—Continued

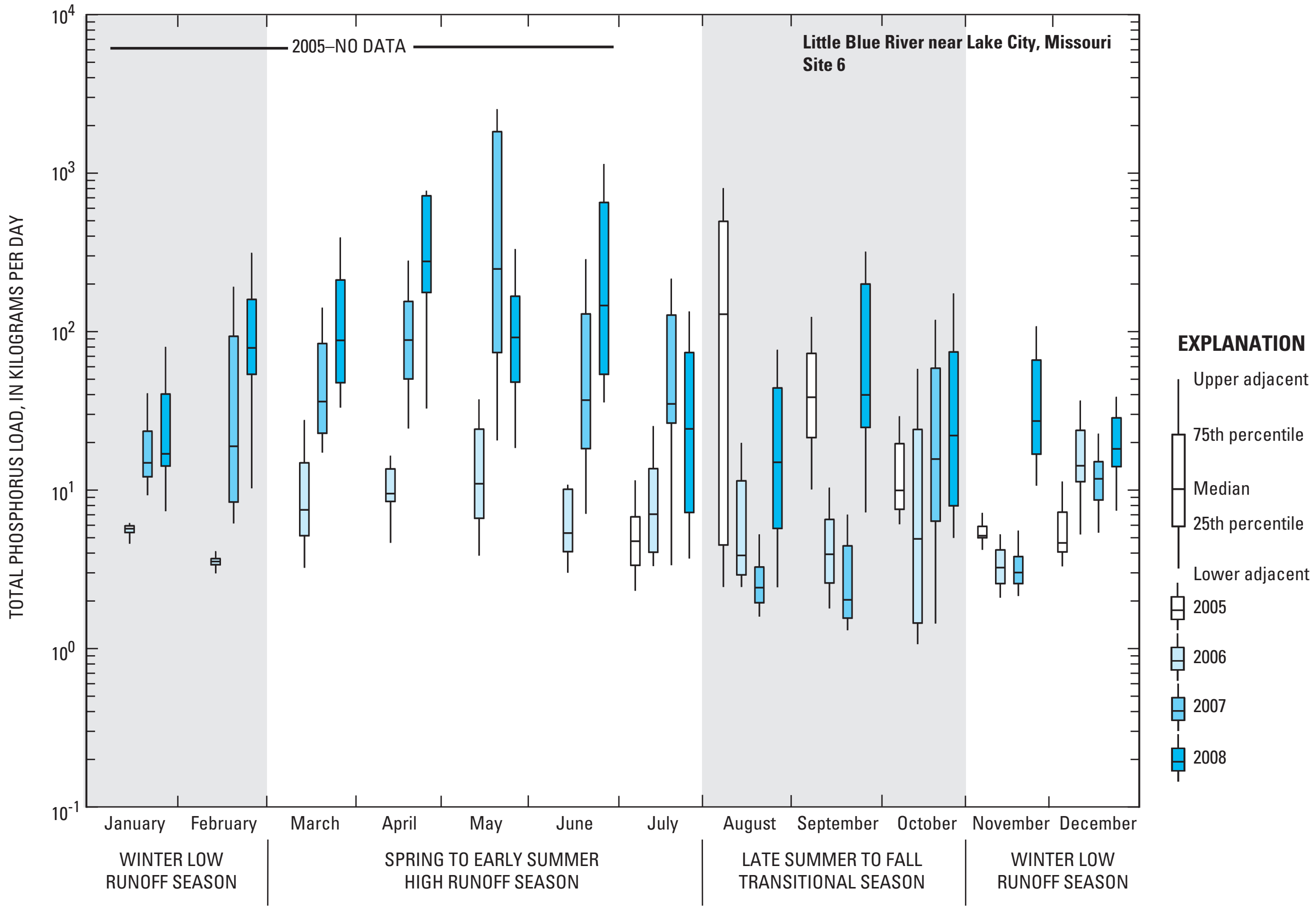


Figure 35. Estimated average daily total phosphorus load by month and year by site, July 2005 through December 2008.—Continued

the MDL used in 1991 and 1992. Schalk (1993) detected no total copper concentrations during dry-weather screening with a MDL of 0.1 mg/L, whereas the provisional MDL for this study was 0.05 mg/L.

There were 225 detections of phenols out of 524 samples that exceeded the EDL of 0.002 mg/L and 131 detections equal to or greater than the provisional MDL of 0.005 mg/L (table 12), with a maximum detection of greater than 0.200 mg/L in the Rock Creek Basin in 2006. The median concentration of phenols in all samples was less than the provisional MDL of 0.005 mg/L (fig. 39). The Missouri chronic standard for AQL for the phenolic compound, phenol, is 0.100 mg/L (Missouri Department of Natural Resources, 2005–2009). The only detection for phenols that exceeded the standard was greater than 0.200 mg/L in a sample from an identified point source in Rock Creek in 2006. In this study, 25.0 percent of samples were equal to or greater than the provisional MDL, but only 1.5 percent were equal to or greater than the MDL used in 1991 and 1992. Schalk (1993) detected no concentrations of phenols using a MDL of 0.02 mg/L.

Out of 535 samples for anionic surfactants, there were 477 detections (table 12) equal to or greater than the EDL of 0.002 mg/L and 256 detections equal to or greater than the provisional MDL of 0.010 mg/L. An arbitrary standard of 0.028 mg/L was used for determining detections (see Methods). There were 51 anionic surfactant detections equal to or exceeding the 0.028 mg/L standard. Five basins had one or more detections exceeding the 0.028 mg/L standard; Rock Creek, Mill Creek, Adair Creek, Crackerneck Creek, and Spring Branch Creek (fig. 38). Rock Creek had 8 detections greater than the standard (14.8 percent of detections in the basin) greater than 0.028 mg/L in 2006, 2 detections (3.8 percent) in 2007, and 15 detections (17.2 percent) in 2008. Mill Creek had 7 detections greater than the standard (13.0 percent). Adair Creek had 5 detections in both 2007 (6.7 percent) and 2008 (9.0 percent) greater than the standard Crackerneck Creek had 4 detections (12.9 percent) and Spring Branch Creek had 5 detections (10.0 percent) greater than 0.028 mg/L. Three basins did not have any detection exceeding 0.028 mg/L: Sugar Creek, Burr Oak Creek, and Bundshu Creek (fig. 38). The largest median concentration of anionic surfactants of 0.017 mg/L was for the Adair Creek Basin in 2008. The maximum concentration of 5.000 mg/L occurred in the Mill Creek Basin in 2007, from the same sample containing grey water that also had the largest concentration of total chlorine. The median concentration of anionic surfactants in the Adair Creek Basin increased from less than the provisional MDL in 2007 to 0.017 mg/L in 2008. For all other basins, the

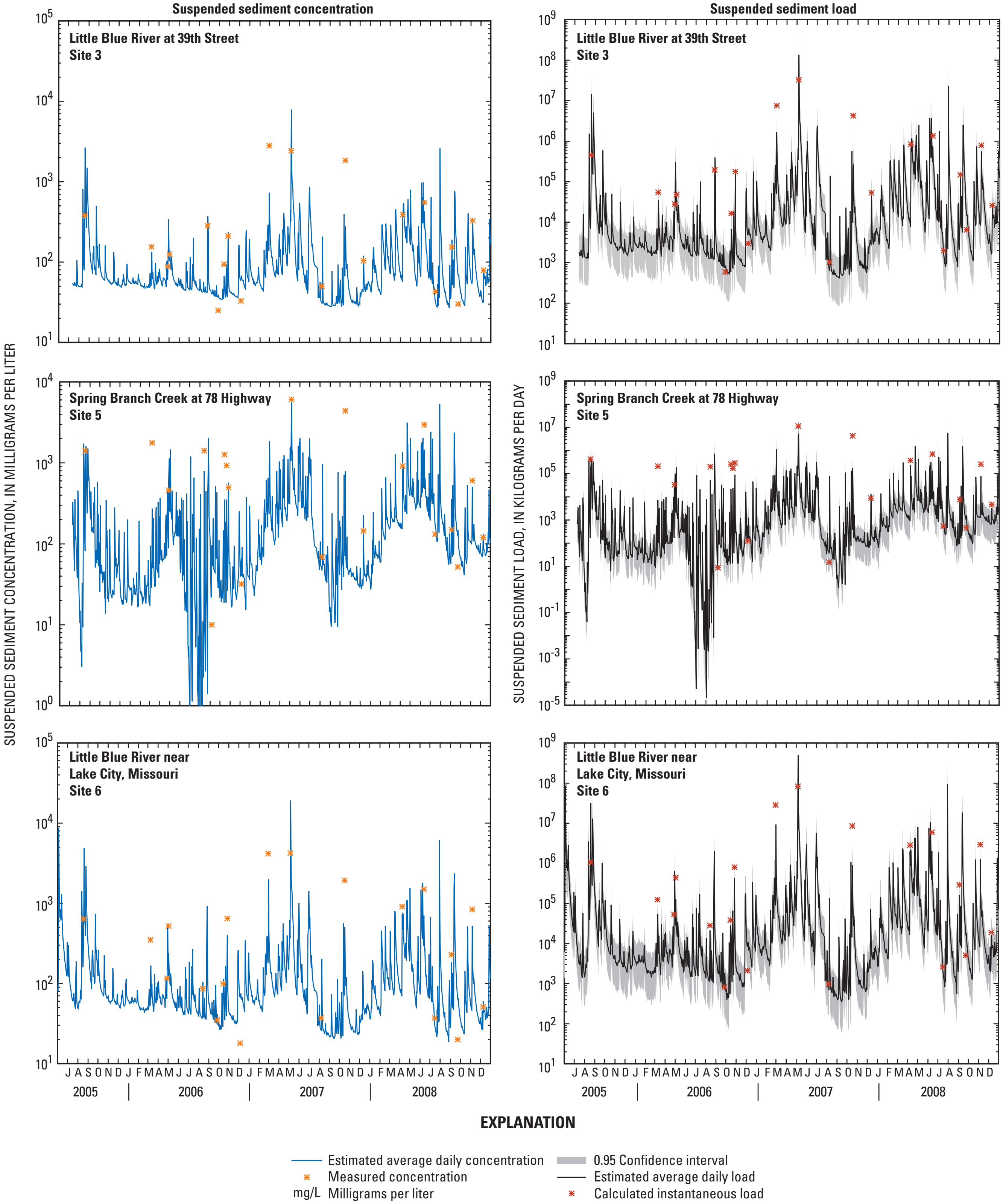


Figure 36. Estimated average daily suspended sediment concentrations and loads by site, July 2005 through December 2008.

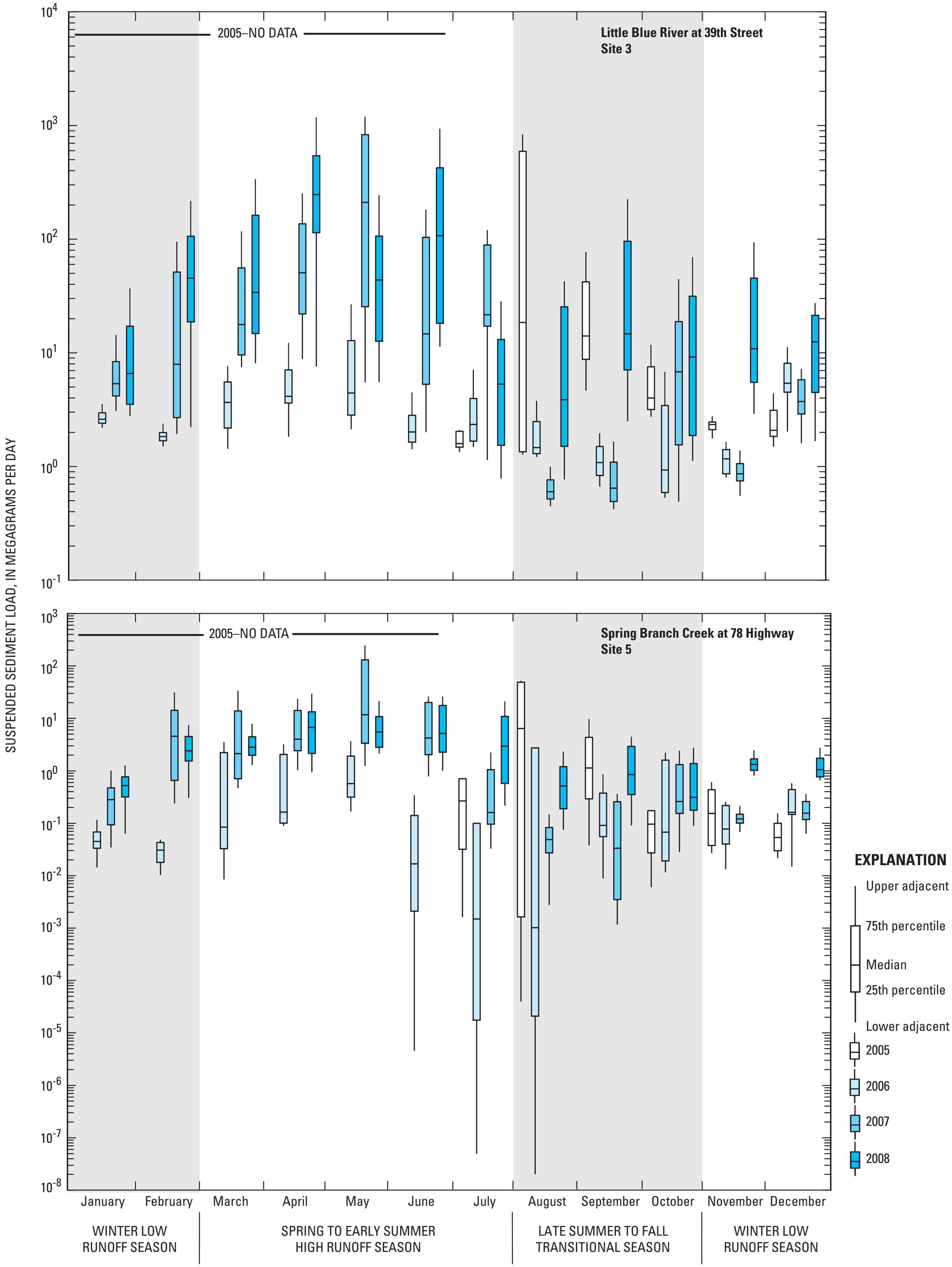


Figure 37. Estimated average daily suspended sediment load by month and year by site, June 2005 through December 2008.

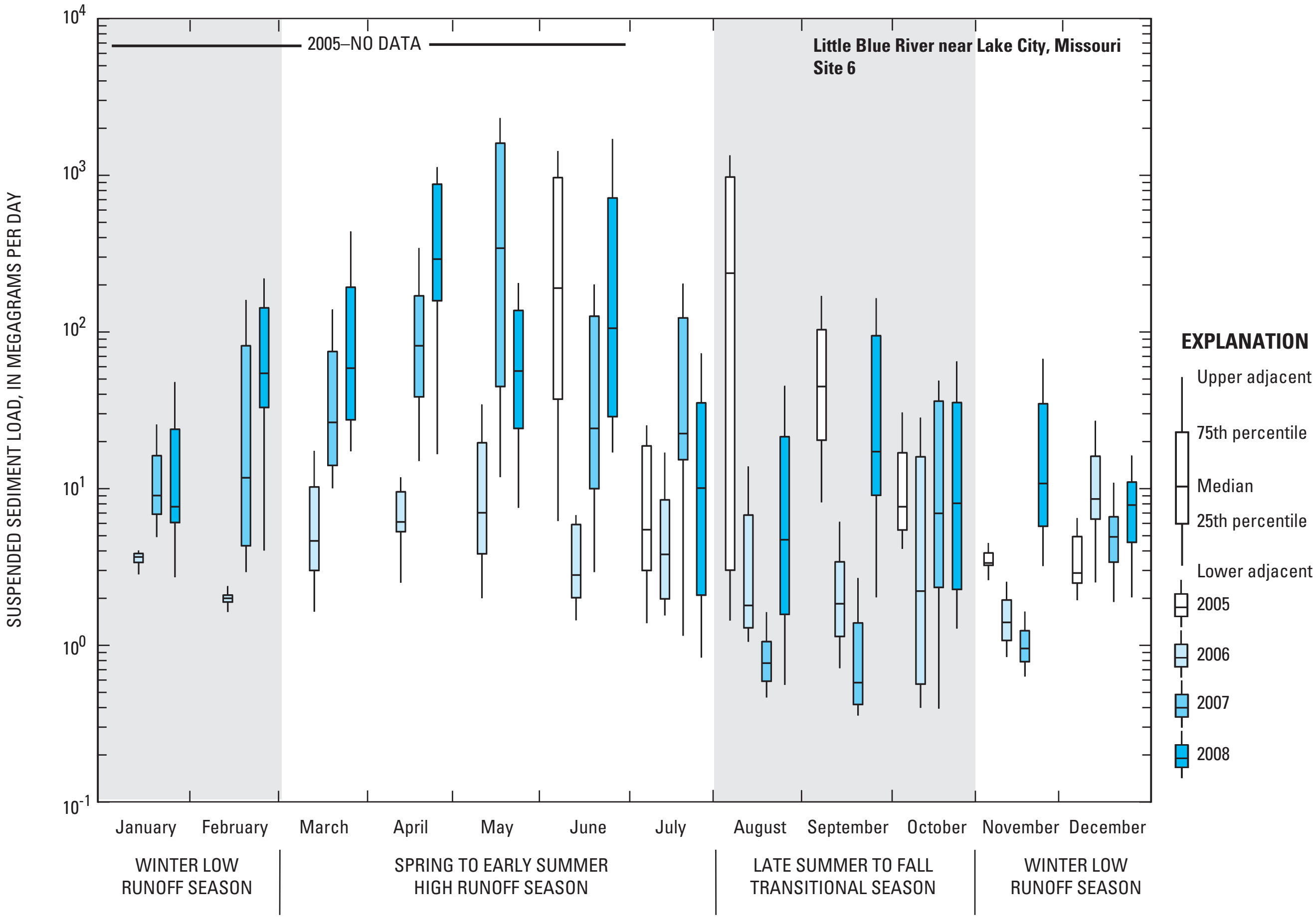


Figure 37. Estimated average daily suspended sediment load by month and year by site, June 2005 through December 2008.—Continued

largest median anionic surfactant concentration was 0.015 mg/L in the Rock Creek Basin in 2008, and the remaining basins had median anionic surfactant concentrations equal to or less than 0.011 mg/L. The median concentration for all anionic surfactant detections was less than the provisional MDL of 0.010 mg/L (fig. 39). In this study, 47.9 percent of samples were equal to or greater than the provisional MDL, but only 4.5 percent equaled or exceeded the MDL used in 1991 and 1992. Schalk (1993) detected total detergents in one sample (0.4 percent) in the Sugar Creek Basin during dry-weather screening using a MDL of 0.05 mg/L.

When considering the basins with detections of anionic surfactants, the three basins that have the fewest detections greater than the provisional MDL of 0.010 mg/L are Sugar Creek, Burr Oak Creek, and Bundshu Creek. Contributing factors to the small number of detections likely are that Burr Oak Creek and Bundshu Creek basins are both located in rural areas of Independence, and Sugar Creek is the smallest basin (10.9 km^2) with the fewest number of samples (8). The other basins (Rock Creek, Mill Creek, Adair Creek, Crackerneck Creek and Spring Branch Creek) are in more developed areas of the city (fig. 3) where the most likely sources of contamination, such as lawn watering and car washing, would be expected to occur more frequently.

During dry-weather screening, in addition to locating several point sources of contamination, large specific conductance values (greater than 2,000 µS/cm) were measured in the Adair Creek Basin (fig. 40) in April 2007 and July 2008, months after the winter road-salt application season. These measured specific conductance values may be indicative of extended residence time of chloride from de-icers in the environment.

Adair Creek flows west to east parallel to I-70. I-70 is categorized as a first priority route with the Missouri Department of Transportation (MODOT) and is treated with more salt per lane mile than other high volume traffic ways including numbered state routes (fig. 2). Additionally, MODOT pre-treats I-70 with a brine solution (rock salt dissolved in water) if snow or icing conditions are imminent (Missouri Department of Transportation, 2006). The largest specific conductance value, greater than 4,000 µS/cm, was measured in a small tributary to Adair Creek adjacent to I-70 (fig. 40). Using the linear regression equations based on data from local area streams (fig. 7), specific conductance values of 4,000 µS/cm would yield estimated chloride concentrations of about 1,100 mg/L or greater.

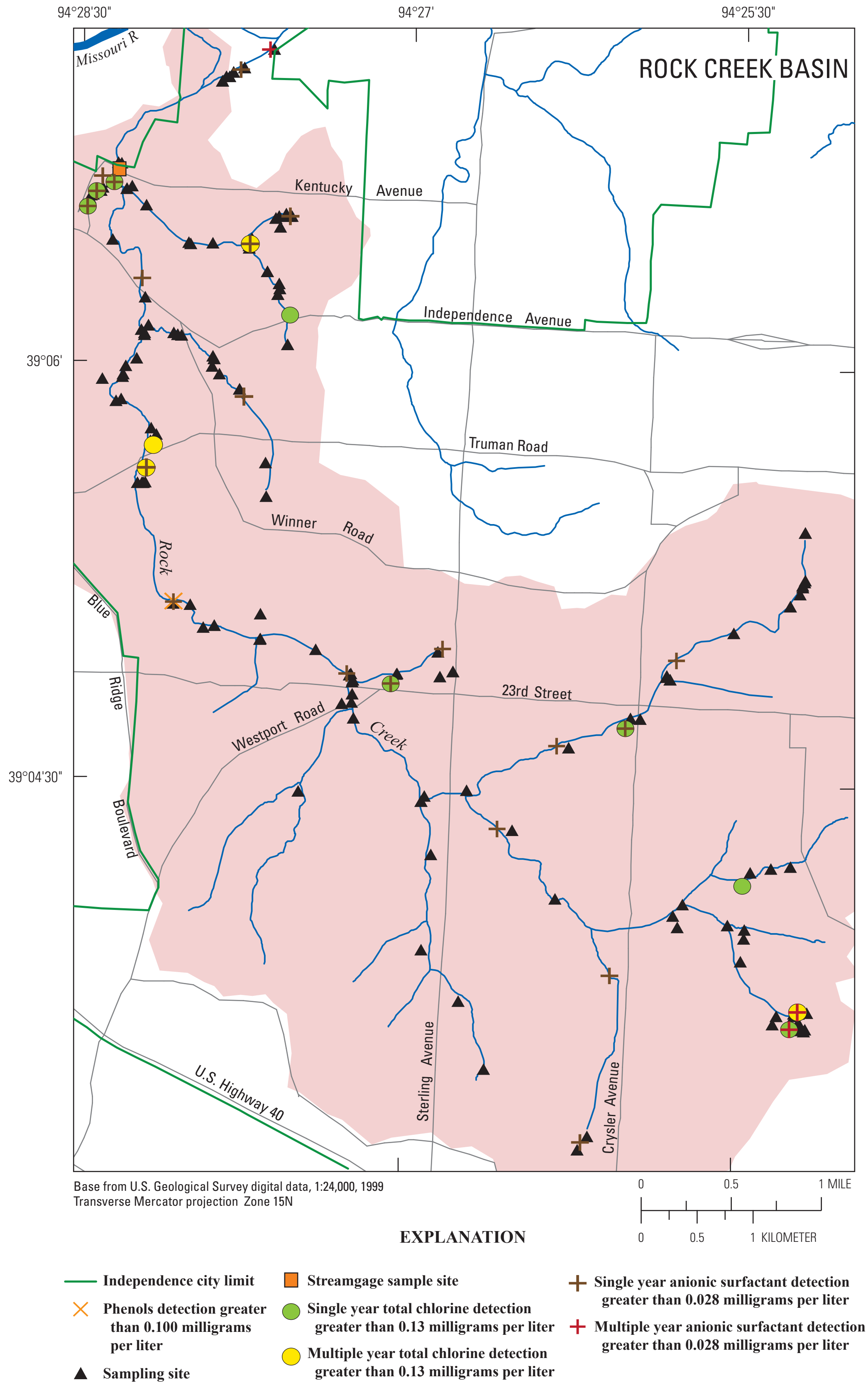


Figure 38. Dry-weather screening sampling sites and location of constituent detections for selected stream basins in Independence, Missouri, 2006 through 2008.

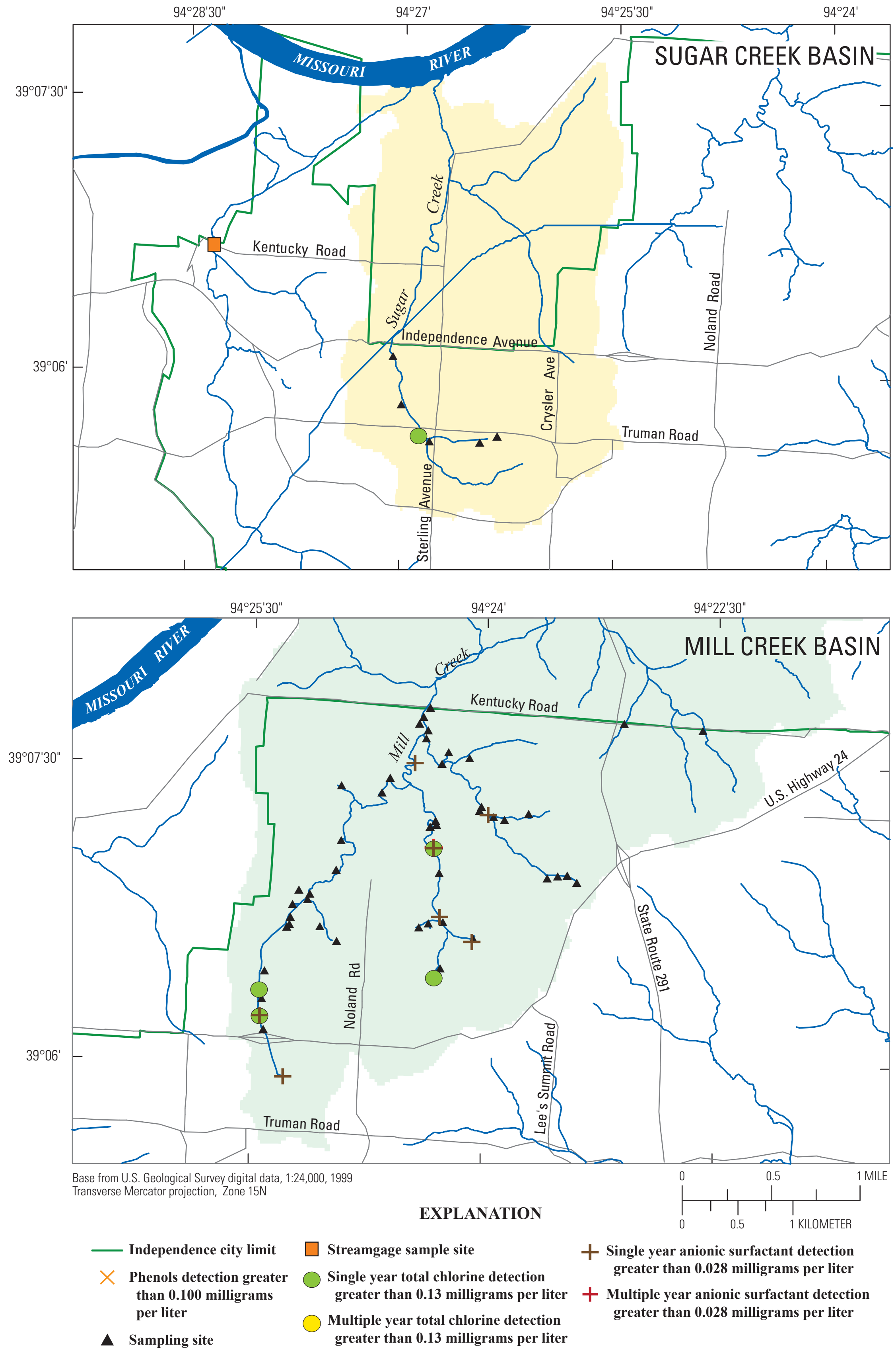


Figure 38. Dry-weather screening sampling sites and location of constituent detections for selected stream basins in Independence, Missouri, 2006 through 2008.—Continued

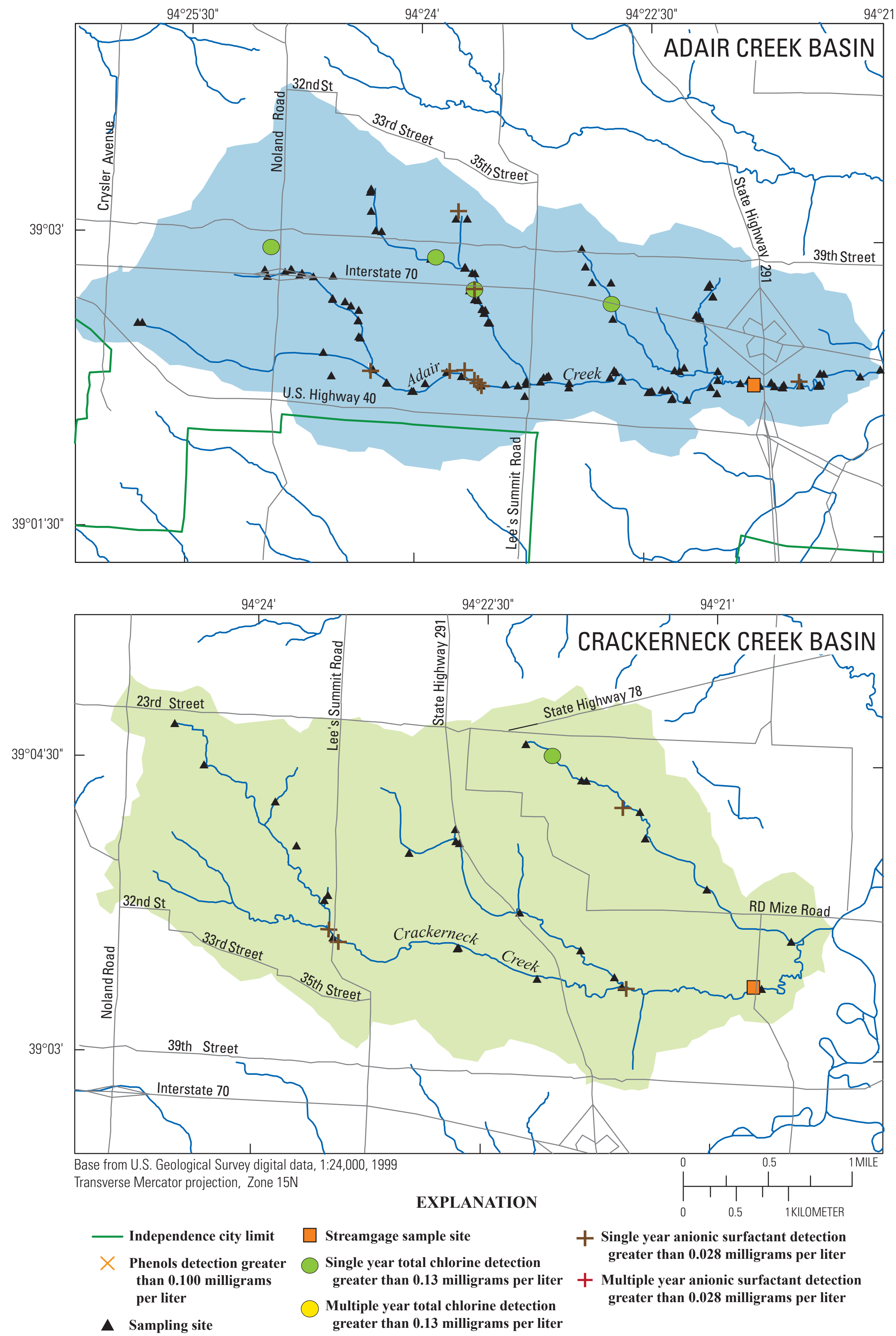


Figure 38. Dry-weather screening sampling sites and location of constituent detections for selected stream basins in Independence, Missouri, 2006 through 2008.—Continued

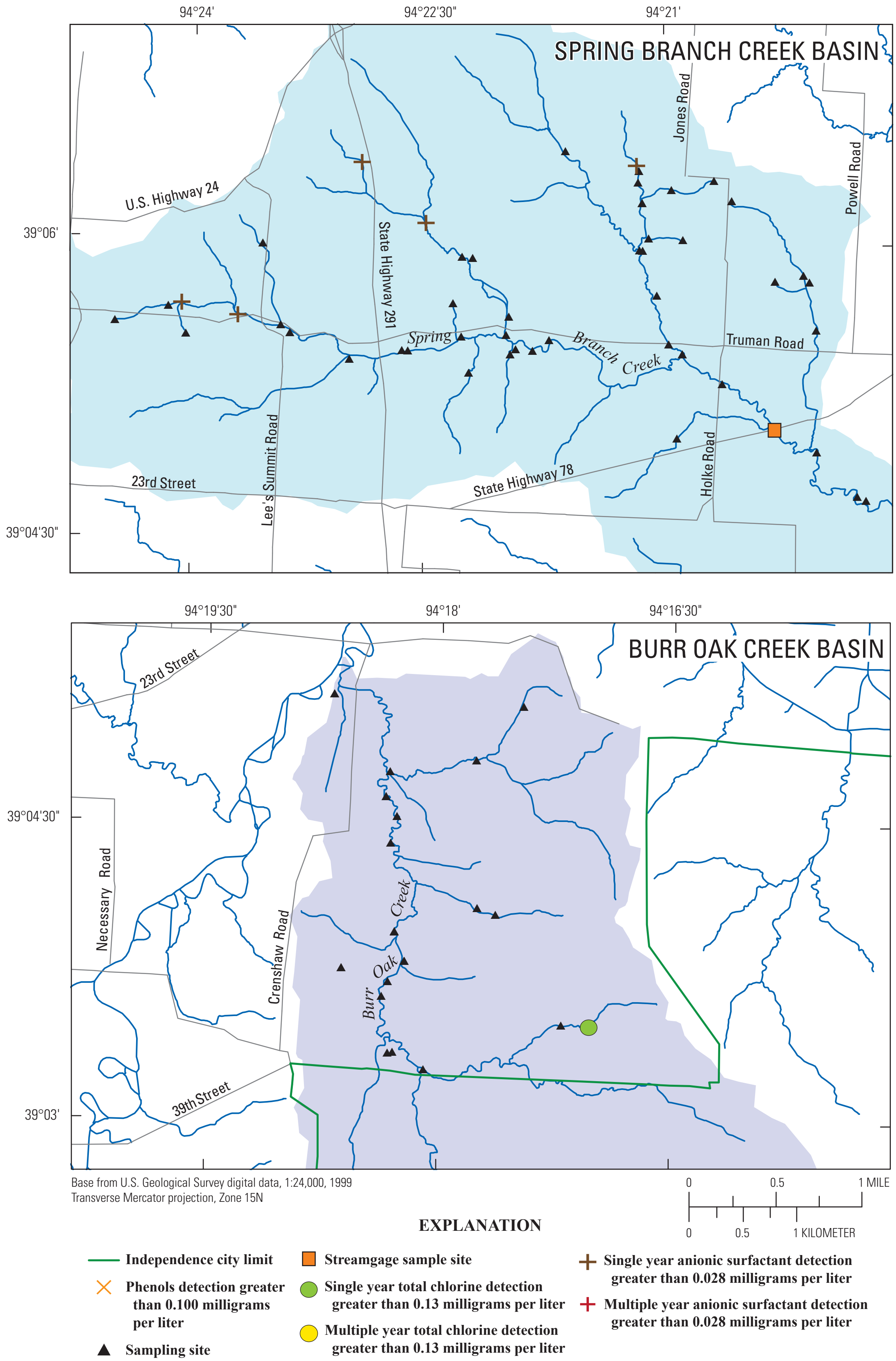


Figure 38. Dry-weather screening sampling sites and location of constituent detections for selected stream basins in Independence, Missouri, 2006 through 2008.—Continued

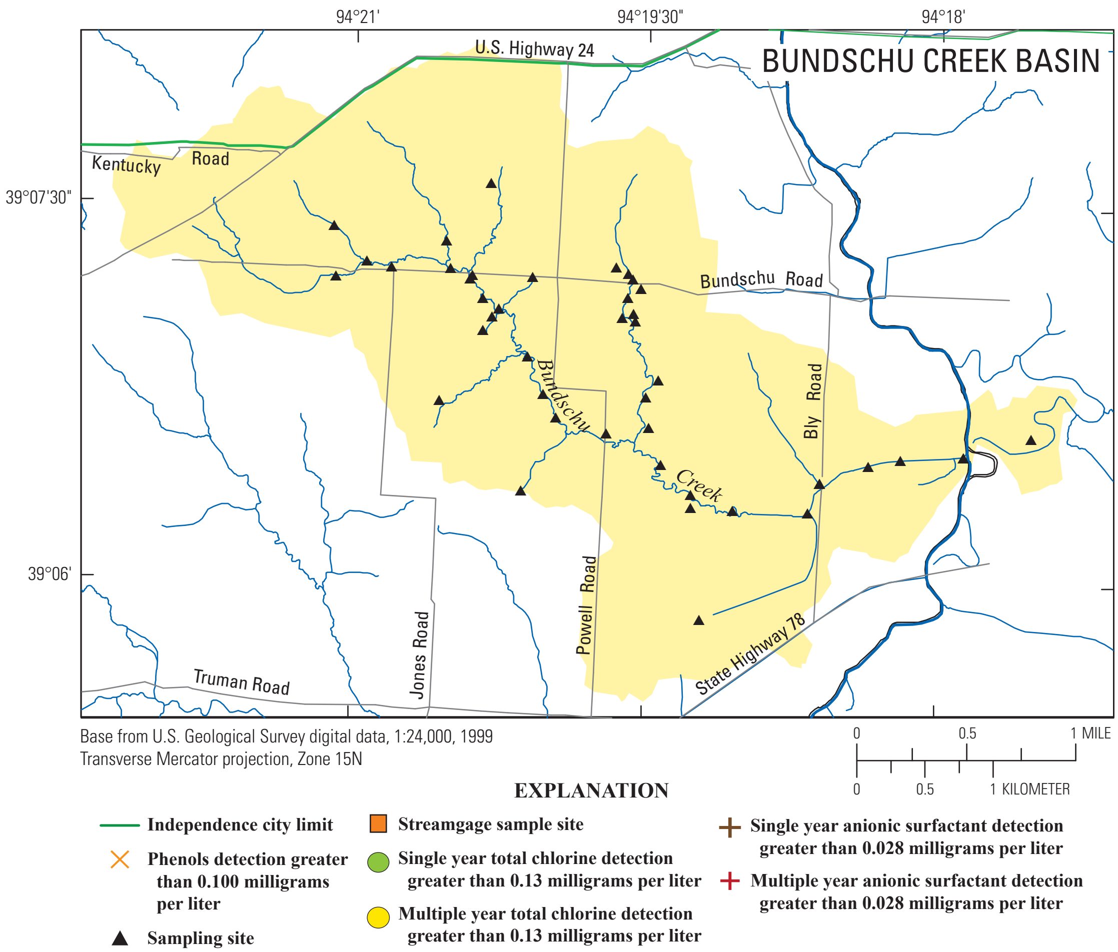


Figure 38. Dry-weather screening sampling sites and location of constituent detections for selected stream basins in Independence, Missouri, 2006 through 2008.—Continued

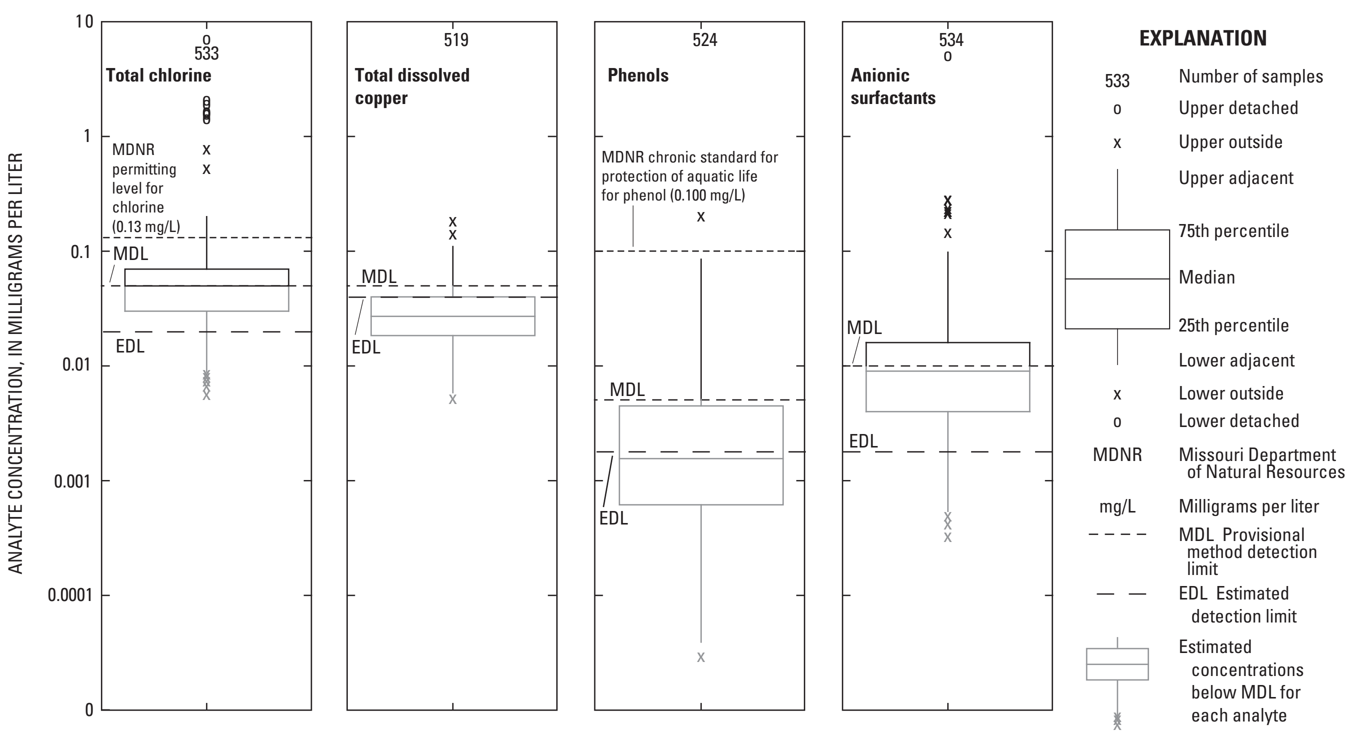


Figure 39. Dry-weather screening constituent concentrations in streams in Independence, Missouri, 2006 through 2008.

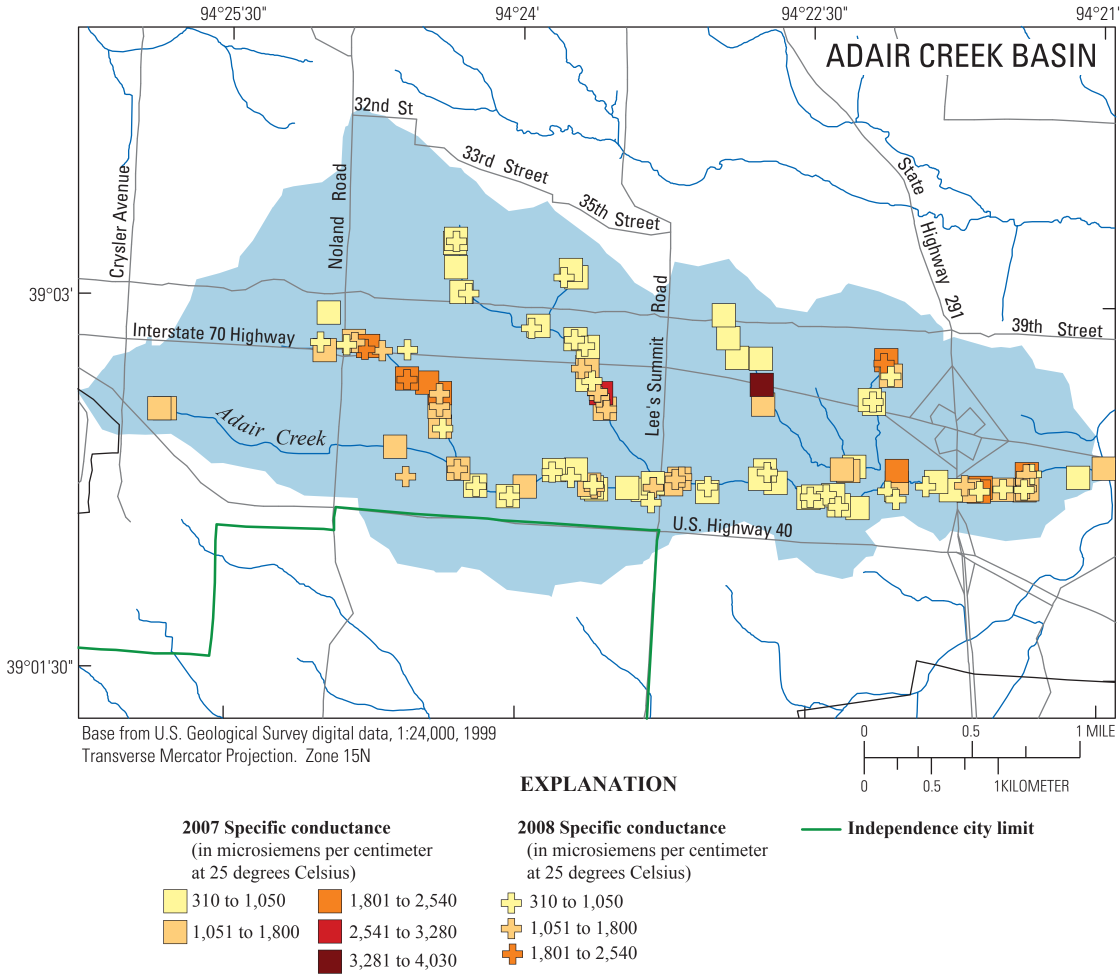


Figure 40. Adair Creek Basin showing locations and measurements for specific conductance during dry-weather screening, April 2007 and July 2008.

Road salt and de-icers can move through the environment in solid form or as dissociated ions in water. The dissociated ions easily enter the soil, are carried into groundwater, and then find their way to the surface and into streamflow (Environment Canada, 2001). Large chloride concentrations can be detected for extended periods of time, even in smaller basins such as the Adair Creek Basin (14.8 km^2), because of the slow movement of road-salt plumes in groundwater. A modeling study by Dougherty (2007) in a 334-km^2 basin in upstate New York indicated that road salt applied at the headwaters can take as much as 79 years to move through the basin.

Bacteria and Microbial Source Tracking

Samples for fecal coliform and *E. coli* were collected along with annual base-flow samples (table 6) and quarterly stormflow samples (table 8) at the five sampling sites (table 1). Densities of fecal coliform are no longer (2010) used by Missouri as a fecal indicator bacteria standard in environmental waters. The following discussion will focus on *E. coli* for which a current (2010) standard exists. Fecal coliform densities are presented in tables 6 and 8 for use with data from other studies and historic water-quality data.

The three streams draining Independence; Rock Creek, Crackerneck Creek, and Spring Branch Creek (sites 1, 4, and 5), had larger median *E. coli* densities during both base flow and stormflow than the Little Blue River sites (fig. 41). *E. coli* densities for base-flow samples for all sites were less than those for stormflow samples. Median *E. coli* densities in base flow (table 6) ranged from 130 col/100 mL for the Little Blue River sites to 770 col/100 mL for Rock Creek, whereas median *E. coli* densities in stormflow (table 8) ranged from 5,800 col/100 mL for the Little Blue River at site 3 to 26,500 col/100 mL for Rock Creek (site 1; fig. 41). Median *E. coli* densities in base-flow samples at sites 3 and 6 were the same. In contrast, median *E. coli* densities in stormflow samples for the Little Blue River increased about 21 percent from upstream site 3 to downstream site 6.

Estimated average daily *E. coli* yields for the study period (table 10) were larger in the smaller urban streams (sites 1 and 5) than in the Little Blue River. However, the estimated annual loads were greater at the Little Blue River sites because of their larger flow volume. Spring Branch Creek had the largest estimated average daily yield with 1,080 billion colonies per square kilometer (col/km^2), followed by Rock Creek with 407 billion col/km^2. Higher suspended sediment concentrations in

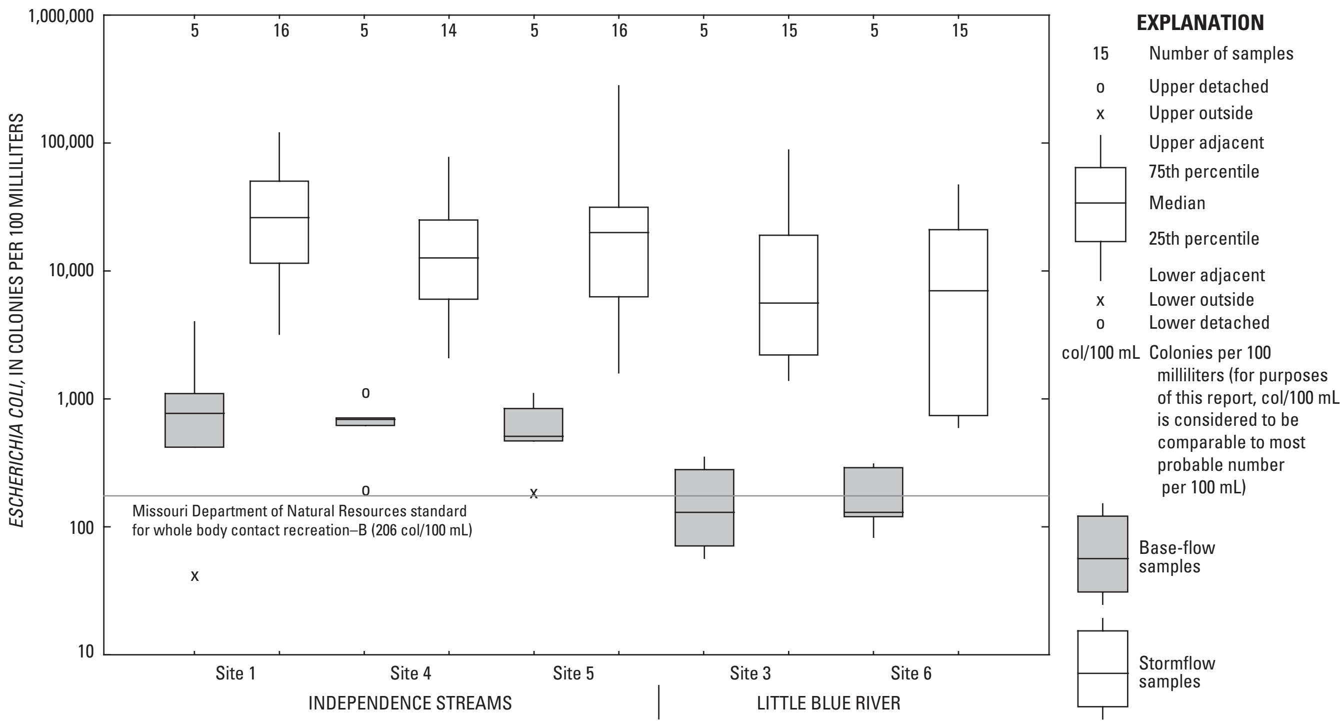


Figure 41. *Escherichia coli* densities by site for base-flow and stormflow samples, June 2005 through December 2008.

the smaller streams likely contribute to larger estimated average daily *E. coli* yields. Even though the estimated average daily *E. coli* yield was less at the Little Blue River sites, the estimated yield nearly doubled from the Little Blue River at site 3 (78 billion col/km^2) to Little Blue River at site 6 (149 billion col/km^2). The estimated annual *E. coli* load was larger at both Little Blue River sites than Spring Branch Creek or Rock Creek for WYs 2007 and 2008; however, the estimated annual *E. coli* load was larger at Spring Branch Creek than at the Little Blue River at site 3 for WY 2006. Because 2006 was a dry year (fig. 10), a greater contribution of *E. coli* loads by smaller streams such as Spring Branch Creek and Crackerneck Creek into the Little Blue River occurred at low flows than during a year with greater precipitation and larger flows. Uncertainties in the regression models for *E. coli* were small with high R^2 between 0.92 and 0.96 and low RMSE between 0.816 and 1.23.

The Little Blue River is designated by MDNR as a whole-body contact recreation category B stream, suitable for whole-body contact recreation, but not specifically designated as a public swimming area. Estimated average daily *E. coli* densities at both Little Blue River sites exceeded the category B standard of 206 col/100 mL about 70 percent of the time (fig. 42). Because measured median *E. coli* densities were exactly the same during base flow for the Little Blue River sites, the contribution of *E. coli* from the streams draining Independence did not, on average, increase *E. coli* densities in the river during base flow. By comparison, data from the adjacent Blue River Basin (Wilkison and others, 2009) that receives discharges from CSOs and wastewater treatment plants indicate *E. coli* densities larger than 206 col/100 mL about 90 percent of the time at the downstream Blue River site. Densities decreased upstream for the Blue River and were greater than 206 col/100 ml between about 10 and 60 percent depending on site location based on data from 2002 to 2007.

For regulatory purposes, a geometric mean of at least five samples is used for calculating *E. coli* densities during the recreation season, April 1 to October 31 (John Ford, Missouri Department of Natural Resources, written commun., 2009). Bacteria counts in individual samples can vary by several orders of magnitude. By using a geometric mean, extremely large or extremely small sampled densities are not unduly weighted. A geometric mean was calculated for the recreation season for 2006 to 2008 using estimated daily *E. coli* densities for both Little Blue River sites (a total of 214 values each year for each site; fig. 43). The geometric estimated mean daily density for the recreation season for the Little Blue River at site 3 was 270 col/100 mL for 2006, 1,100 col/100 mL for 2007 and 1,800 col/100 mL for 2008. For the Little Blue River at site 6 the estimated mean daily density for the recreation season was 330 col/100 mL in 2006, 1,100 col/100 mL in 2007 and 1,700 col/100 mL in 2008.

Estimated average daily *E. coli* densities and loads show seasonal variability (fig. 43) that are likely related to such factors as variation in seasonal runoff and water temperature. *E. coli* densities in this study exhibit positive correlation with

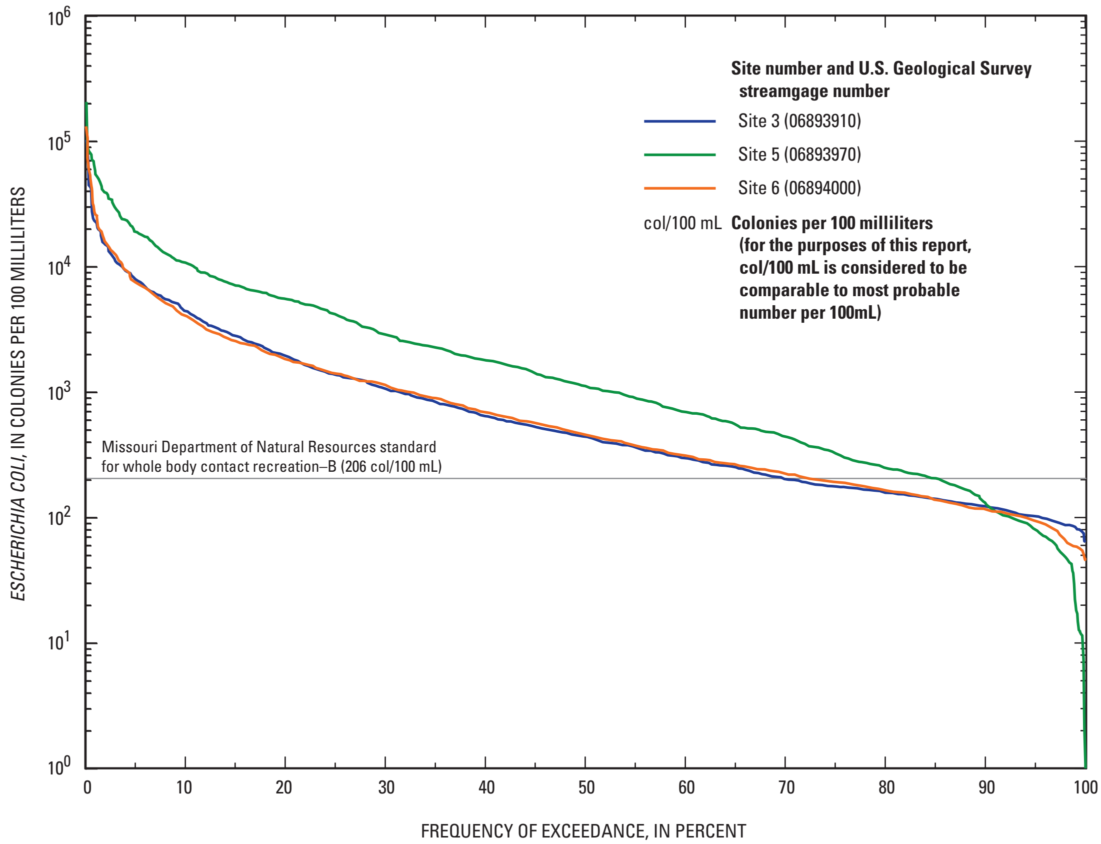


Figure 42. Frequency of exceedance for estimated average daily *Escherichia coli* densities by site, July 2005 through December 2008.

suspended sediment concentrations (fig. 44) and turbidity. The sinusoidal patterns for estimated average daily *E. coli* densities and loads (fig. 43) are because of the explanatory variables in the regression equations (table 10) that reflect the seasonality of these factors (variables containing sin and cos). Wilkison and others (2006) noted a similar pattern for the nearby Brush Creek Basin in Kansas City, Missouri, with greater bacteria densities in late spring or early summer and lesser densities in the winter.

Some fecal indicator bacteria, including *E. coli*, can survive for extended periods in bottom sediments (Burton and others, 1987; Davies and others, 1995; Jamieson and others, 2005) and can have densities thousands of times greater than in the stream (Jolley and others, 2008). During a storm, these bottom sediments can be re-suspended resulting in larger concentrations and increased bacteria densities. Most of the increase in bacteria densities likely occurs as the stream stage rises. Jamieson and others (2005) noted that the quantity of bacteria available for re-suspension is limited during individual storms.

Generally, maximum estimated bacteria densities and loads for all sites occurred during May and June, and minimum bacteria densities occurred in December and January, when it is usually the driest, and runoff and water temperature lowest (fig. 45). Water temperature is important in bacteria survivability and growth. Studies have shown that *E. coli* can grow over a considerable range of temperatures (7 to 49°C) with maximum growth rates between 20 and 40 °C. Below 7 °C and above 49 °C, *E. coli* can survive, but the growth rates are curtailed, if not halted altogether (Winfield and Groisman, 2003; Jones and others, 2004; Ishii and Sadowsky, 2008).

At Spring Branch Creek, modeled bacteria densities during the summer of 2006 were low compared to the rest of the study because streamflow was near zero (figs. 9 and 43).

In addition to season being an important determining factor, land use historically has been thought to affect bacteria densities with urban land use and high percentage of impervious surface basins having larger bacteria densities in streams (Mallin and others, 2000; Paul and Meyer, 2001). More recent studies (Byappanahalli and others, 2003; Jolley and others, 2008) indicate that land disturbance, such as deforestation and excavation of sediments in construction operations, can actually contribute more to an increase in bacteria densities than when there is an established land use, including developed and more urban land uses. Bacteria from fecal material are more readily transported to streams in the absence of vegetated buffer areas along drainages and streams (Sullivan and others, 2007), which is often the case in disturbed construction areas. Since this study began in 2005, an increase in construction activity has occurred in areas of Independence near the Little Blue River, including observed construction activity in the lower Adair Creek, Crackerneck Creek, and Spring Branch Creek basins. For example, since 2005 about 1.3 km^2 have been cleared and developed in the lower Crackerneck

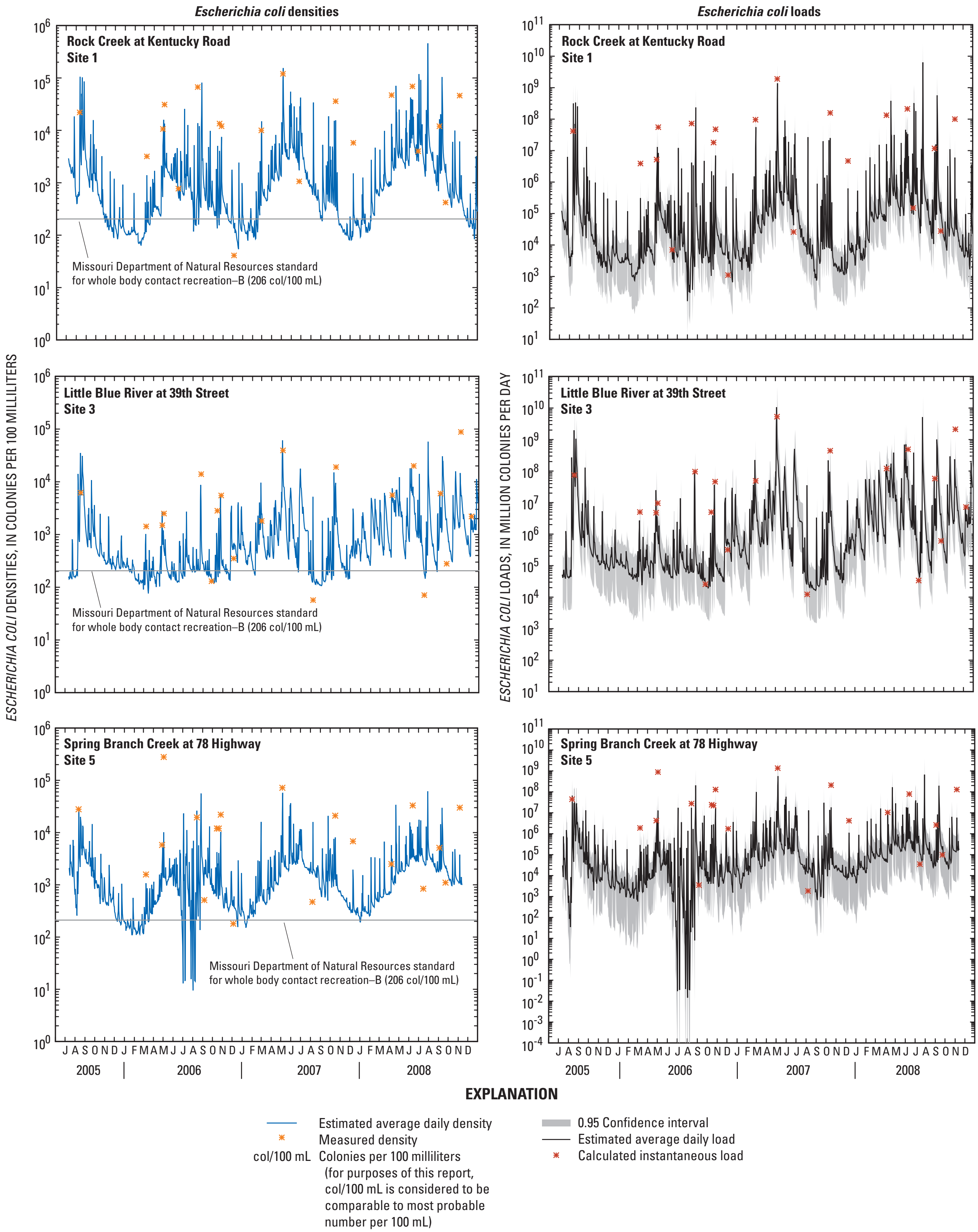


Figure 43. Estimated *Escherichia coli* bacteria densities and loads by site, July 2005 through December 2008.

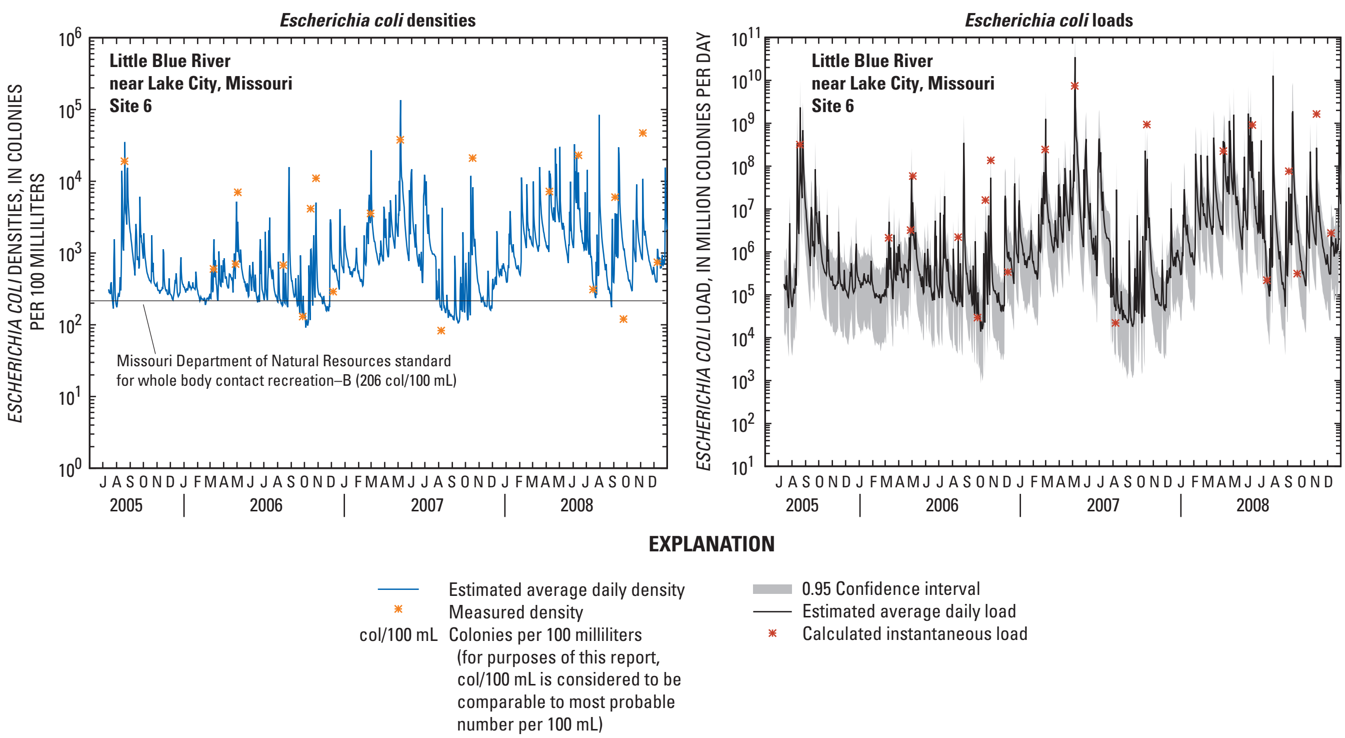


Figure 43. Estimated *Escherichia coli* bacteria densities and loads by site, July 2005 through December 2008.—Continued

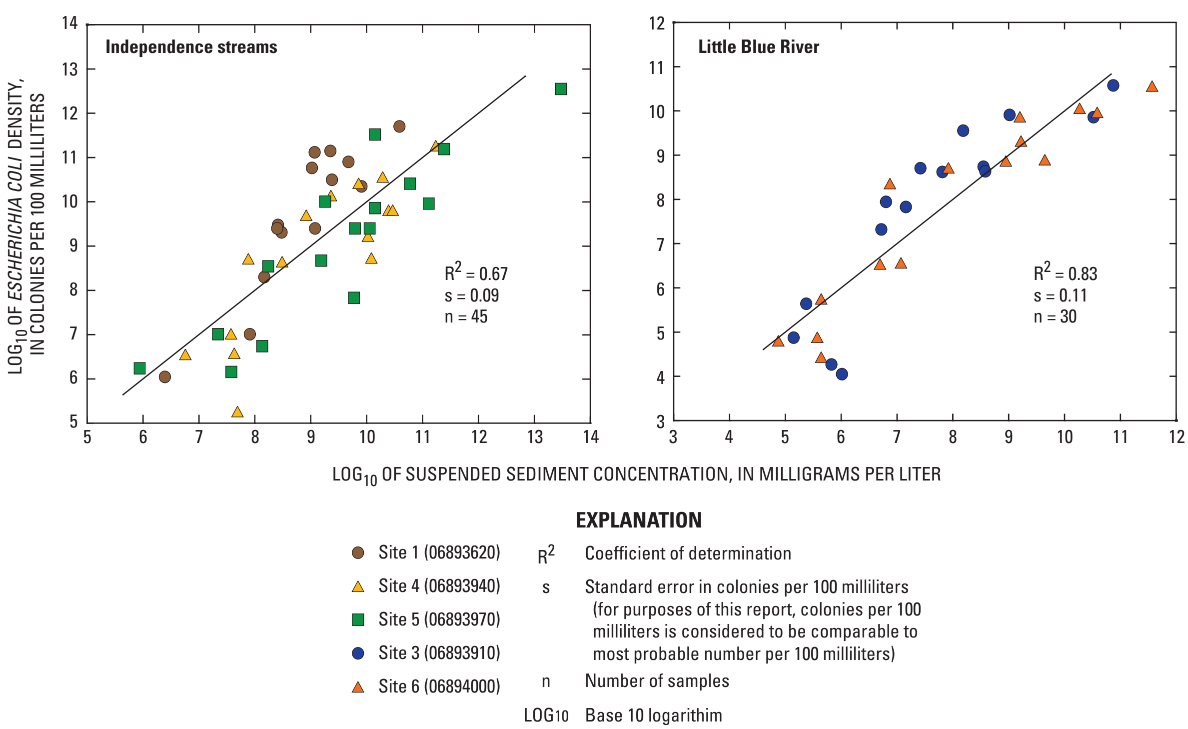


Figure 44. Relation between *Escherichia coli* bacteria density and suspended sediment concentration for Independence streams and the Little Blue River.

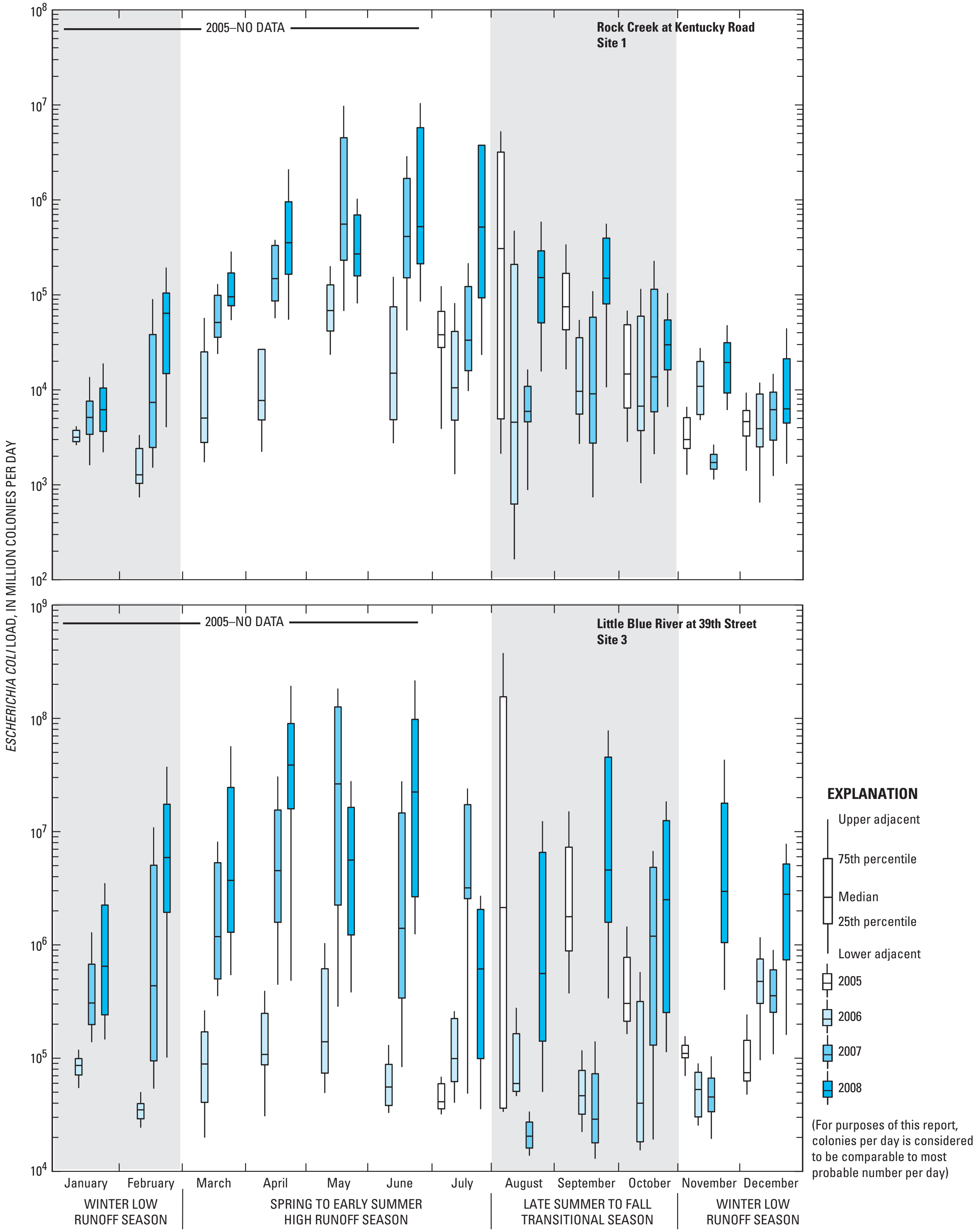


Figure 45. Estimated daily *Escherichia coli* load by month and year by site, June 2005 through December 2008.

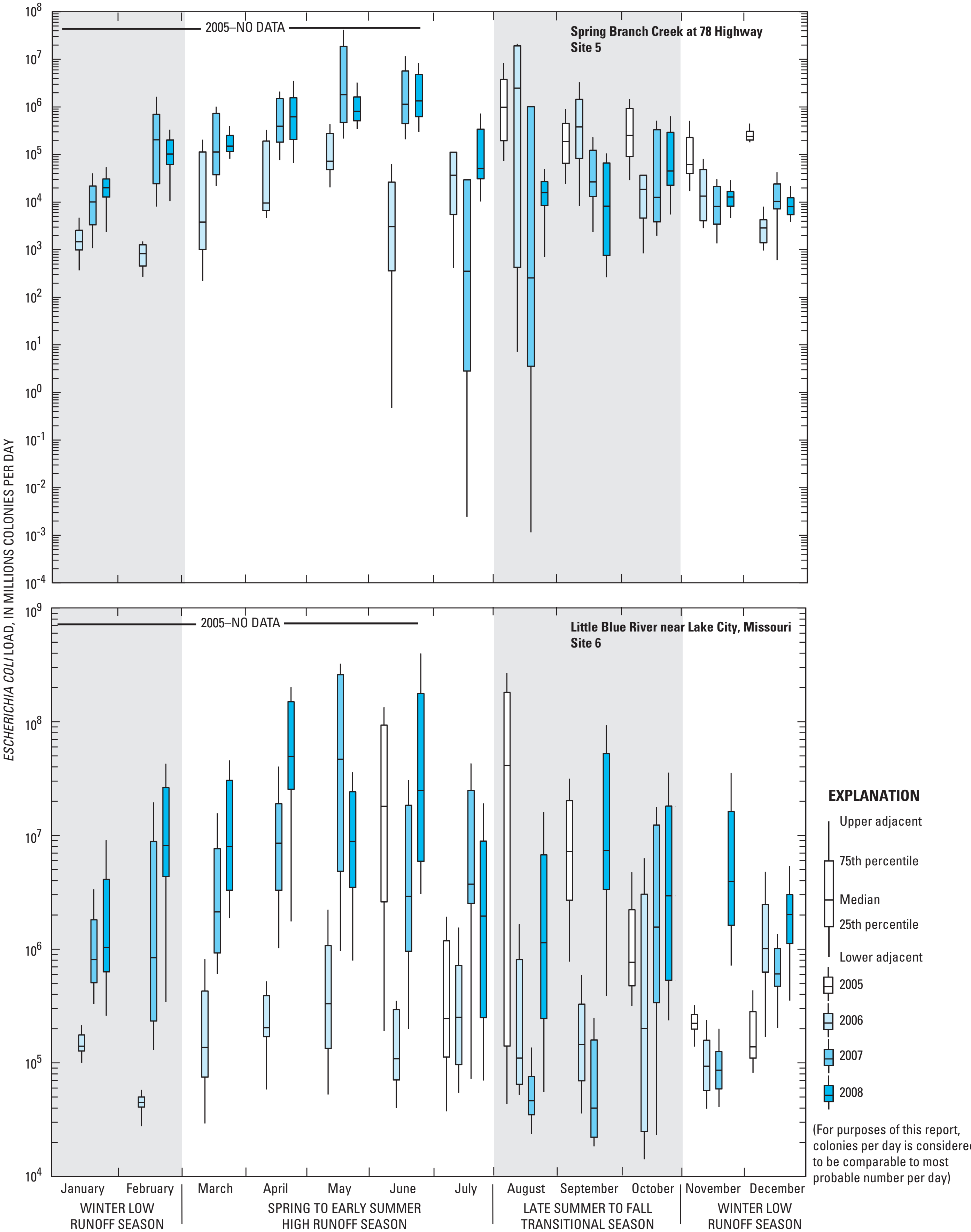


Figure 45. Estimated daily *Escherichia coli* load by month and year by site, June 2005 through December 2008.—Continued

Creek and Spring Branch Creek basins (Stuart Borders, City of Independence, Planning and Zoning Division, oral commun., 2009), about 3.4 percent of the combined areas of the two basins. Even with implementation of BMPs for sediment control, large development projects in Independence have most likely contributed to larger suspended sediment concentrations during stormflow and larger fecal indicator bacteria densities than would otherwise be expected in the absence of construction activity. The largest *E. coli* densities measured were from a storm sample for Spring Branch Creek that also had the largest measured suspended sediment concentration. However, upstream reservoirs on the Little Blue River likely act to lessen bacteria densities and loads by attenuating high flows and trapping suspended sediment.

Sources of *E. coli* bacteria in streams were evaluated using MST methods to identify host sources (Carson and others, 2001; Dombek and others, 2000). Elevated fecal bacteria densities in streams are a concern because MST indicates that a substantial part of in-stream *E. coli* in the local area can be of human origin and is evident in both base flow and stormflow (Wilkison and others, 2009).

Samples from Rock Creek, Crackerneck Creek, Spring Branch Creek, and the Little Blue River (sites 1, 3, 4, 5, and 6; fig. 2) were analyzed for host sources of *E. coli* bacteria during one base-flow and two stormflow samplings in May through October 2007 (table 13). For MST analyses, a presumptive source of sampled bacteria is assigned through a statistical comparison of genetic markers obtained from environmental *E. coli* samples to genetic markers in a host-source library. A library of patterns developed for other studies in the local area (Wilkison and others, 2005, 2006) was used for the purposes of this study. A minority of *E. coli* (0 to 27.8 percent) from samples collected in 2007 were identified to be from human sources using MST methods. Crackerneck Creek (site 4) showed the largest percentage of human sources of *E. coli* (26.7 percent) for base-flow samples. For the Little Blue River stormflow sample in May 2007, 50.7 percent of the *E. coli* was identified as having non-human sources, whereas 12.0 percent were determined to be from human sources and 37.3 percent from unknown sources. Results for the Little Blue River stormflow sample in October 2007 were similar with 14.5 percent of the *E. coli* determined to be from human sources. Percentages of *E. coli* from human sources in stormflow samples in the three smaller streams were larger (20.0 to 27.8 percent) than for the Little Blue River. However, for the base-flow sample in August 2007, although there were a greater percentage of identified non-human sources for the Little Blue River than for stormflow samples, the percentage of human sources of *E. coli* was similar to stormflow. Human-source *E. coli* likely originates from leaky sewer systems in the older parts of the Crackerneck Creek Basin and less developed areas of the Spring Branch Creek Basin.

A more rigorous study done in the Blue River Basin in Kansas City, 1998 to 2004 (Wilkison and others, 2006) indicated that during base flow, the presumptive source of *E. coli* was nearly equal for humans (42 percent) and non-humans (40 percent). Caution is advised in drawing conclusions from this study about the characterization of bacteria sources in the Rock Creek and Little Blue River basins because of the small number of samples.

Table 13. Presumptive host sources of *Escherichia coli* in samples collected May through October 2007.

[*E. coli, Escherichia coli*]

Sample date	Sample type	Site number (table 1; fig. 1)	*E. coli* (number of colonies)	Presumptive host source (percentage of colonies)		
				Dog and goose	Human	Unknown or unclassified
5/8/2007	Stormflow	3 and 6	77,000	50.7	12.0	37.3
10/18/2007	Stormflow	1	35,800	50.0	20.0	30.0
10/18/2007	Stormflow	4	18,000	33.3	27.8	38.9
10/18/2007	Stormflow	5	21,000	50.0	22.2	28.0
10/18/2007	Stormflow	3 and 6	40,000	38.2	14.5	47.3
8/7/2007	Base flow	4	190	40.0	26.7	33.0
8/7/2007	Base flow	5	470	25.0	0	75.0
8/7/2007	Base flow	3 and 6	140	69.2	15.4	15.4

Ecological Condition

Surveys of benthic macroinvertebrate populations were conducted for five study sites (sites 1, 3, 4, 5, and 6) and two reference sites (sites 7 and 8) in March 2007 and 2008 and September 2008 (table 1, fig. 1). Habitat assessments were conducted in September 2008 at four study sites (sites 1, 3, 5, and 6) and the two reference sites (sites 7 and 8; table 1). Crackerneck Creek (site 4) did not have a habitat assessment conducted because of habitat alteration caused by road and bridge construction.

Macroinvertebrate Surveys

Macroinvertebrate sampling sites in the study area were all located at downstream locations for each stream except for Little Blue River site 3 (fig. 2). Therefore, samples collected at these sites may be expected to give a conservative representation of the health of the macroinvertebrate community over the entire length of the stream. Studies by Wilkison and others (2006, 2009) and Poulton and others (2007) in the adjacent Blue River Basin (fig. 1) and in nearby Johnson County, Kansas (Poulton and others, 2007) have indicated that as urban land use and associated factors increased downstream in the Blue River Basin, macroinvertebrate community abundance and diversity decreased. Also, the largest abundances and diversity were found in streams with lesser amounts of urbanization and wastewater discharge. During macroinvertebrate sample collection for this study (table 14), 195 different taxa were identified. During this study, the TTR identified in individual samples after assignment of parents to children ranged from 17 to 42 (table 14). The lowest TTR of 17 taxa at reference site 7 in September 2008 was from a sample collected at a site previously sampled in the spring of 2008 that had the largest TTR of 42 taxa. After an extended period of sedimentation during late spring and summer, preferred habitat for sample collection was reduced.

Four calculated metrics, TTR, EPTR, BI, and the SDI were normalized and summed to produce a composite SCI. A SCI of 16 to 20 indicates a habitat fully biologically supportive (FBS) of aquatic life, a score of 10 to 14 is partially biologically supportive (PBS), and a SCI of 4 to 8 is non-biologically supportive (NBS). Most of the samples scored a rating of PBS. No samples were rated FBS, and five samples had a calculated rating of NBS. Reference streams typically score as FBS (Sarver and others, 2002), however for this study, the reference streams, sites 7 and 8, had an average SDI score of 12 within the PBS category. Site 8, South Grand River below Freeman, also was a reference site in studies by Wilkison and others (2009) and Poulton and others (2007) and did not score above PBS for five samples collected from 2002 through 2007. One sample at site 7, rated NBS, was collected from poor, heavily sedimented habitats. The SCI scores for macroinvertebrate samples collected in the study area compared closely with those from the less urbanized reference sites and were rated PBS. The Little Blue River sites (sites 3 and 6) had an average SCI score of 12, and the streams draining Independence (sites 1, 4, and 5) had an average SCI score of 10.

Ecologists commonly assume when assessing a stream in an aquatic ecosystem that as the number of taxa increase in an aquatic ecosystem, with relatively equal abundance among taxa, diversity and stream health increase (Sarver and others, 2002). The abundance and average pollution tolerance of the five most abundant taxa are presented in table 14. An average dominant taxa pollution tolerance greater than or equal to 7.0, expressed on the same scale as the BI, indicates the dominance of pollution tolerant taxa. The average pollution tolerance score for the Little Blue River sites of 6.3 was less than the average score of 6.8 for the streams draining Independence, but both were less than 7.0. These scores were similar to the 6.5 average score for reference site 8. The average pollution tolerance score of 7.8 for reference site 7 may be affected by poor site conditions and sedimentation.

Habitat Assessments

Habitat assessments were conducted at four of the five macroinvertebrate sampling sites and at two reference sites (table 1) in late August and early September 2008. An assessment was not conducted for Crackerneck Creek (site 4) because road and bridge construction had disrupted the reach of stream previously used for macroinvertebrate sample collection. The site was discontinued in October 2008. Habitat assessments measure 10 different factors that affect the condition of stream habitat. The highest possible score of 170 represents ideal habitat for benthic macroinvertebrates. Habitat scores for the Independence sites (table 15) ranged from 88 for Rock Creek and the upstream Little Blue River site (sites 1 and 3) to 97 for Spring Branch Creek (site 5). Reference sites had scores of 62 for the East Fork Crooked River near Richmond (site 7) and 116 for the South Grand River below Freeman (site 8). Both the habitat assessment score and the macroinvertebrate sample collected later in September 2008 at site 7 were adversely affected by erosion and slumping of the stream banks and sediment and woody debris deposition earlier in the year (fig. 46). An example of more suitable habitat for a reference site at South Grand River is shown in figure 47.

As a result of the wet conditions and resultant sediment deposition and erosion during much of 2007, scores for embeddedness, sediment deposition, bank stability, and vegetative protection were less at all six sites (table 15) than what might otherwise be expected. Wilkison and others (2009) gave site 8 a score of 139 in 2006 as compared to 116 in this study; the difference in scores was largely attributable to lower scores in this study because of sediment deposition and bank stability. Overall, for the four study sites, the assessment factors having the most affect on suppressing scores were high sediment deposition, channel alteration, poor bank stability, and loss or absence of bank and riparian vegetation.

Table 14. Benthic macroinvertebrate sample abundance and calculated metrics for sites sampled from March 2007 through September 2008.

[EPT, Ephemeroptera-Plecoptera-Trichoptera; BI, Biotic Index; SDI, Shannon Diversity Index (base e); SCI, Stream Condition Index; S, spring, PBS, partially biologically supporting; NBS, non-biologically supporting; F, fall]

Site number (table 1; fig. 1)	Sample period	Year	Total taxa richness	EPT taxa richness	BI	SDI	Tolerant taxa (percent)	Intolerant taxa (percent)	Dominant taxa abundance[1] (percent)	Dominant taxa tolerance[2]	SCI	SCI rating
1	S	2007	28	5	6.39	2.28	44.4	11.1	75.7	6.6	10	PBS
1	S	2008	26	4	6.54	2.37	40.0	8.0	68.8	7.7	8	NBS
1	F	2008	26	6	6.05	2.60	44.0	12.0	61.4	6.2	12	PBS
3	S	2007	35	6	5.99	2.37	41.2	8.8	71.7	6.5	14	PBS
3	S	2008	37	8	6.21	2.37	47.2	5.6	68.4	6.7	14	PBS
3	F	2008	25	9	5.89	2.29	29.2	20.8	75.0	6.2	12	PBS
[3] 4	S	2007	32	5	6.55	2.67	50.0	6.3	61.5	7.0	8	NBS
4	S	2008	32	4	5.74	2.39	37.5	6.3	74.9	5.8	10	PBS
4	F	2008	27	5	6.59	2.66	53.9	3.9	62.4	7.4	10	PBS
5	S	2007	27	4	7.22	2.42	65.4	3.9	72.7	7.6	8	NBS
5	S	2008	28	4	6.35	2.30	46.4	3.6	74.9	6.5	8	NBS
5	F	2008	30	8	5.98	2.49	37.9	13.8	65.8	6.6	12	PBS
6	S	2007	34	10	5.53	2.18	36.4	21.2	78.1	6.3	12	PBS
6	S	2008	34	10	5.78	2.52	42.4	21.2	65.1	6.0	12	PBS
6	F	2008	29	10	5.15	1.80	32.1	21.4	79.1	6.2	12	PBS
7	S	2007	35	4	6.36	2.29	45.5	9.1	79.4	7.2	10	PBS
7	S	2008	42	11	6.85	2.74	42.5	20.0	65.2	7.8	12	PBS
[4] 7	F	2008	17	5	7.96	1.92	64.7	11.8	78.6	8.3	8	NBS
8	S	2007	33	8	6.07	2.23	33.3	21.2	71.3	6.6	12	PBS
8	S	2008	31	9	6.23	2.13	38.7	19.4	75.8	6.7	12	PBS
8	F	2008	31	11	5.73	2.24	35.5	19.4	76.8	6.1	12	PBS

[1]Sum of the five most abundant taxa expressed as a percentage of the total abundance.

[2]Abundance weighted average of the pollution tolerance values for the five most abundant taxa.

[3]Sample collected at the Holke Road site for Spring Branch Creek (original location of site 5; fig. 2).

[4]Poor sampling conditions because of recent sedimentation.

Table 15. Stream habitat assessment scores for macroinvertebrate sampling sites, 2007 and 2008.

[--, no data]

Site number (table 1; fig. 1)	Site name	Epifaunal substrate	Embed-dedness	Velocity/ depth regime	Sediment deposition	Channel flow status	Channel alteration	Riffle quality	Bank stability	Vegetative protection	Riparian vegetation	Total score
1	Rock Creek at Kentucky Road in Independence, Mo.	19	15	7	3	15	6	15	3	3	2	88
3	Little Blue River at 39th Street in Independence, Mo.	17	18	7	3	15	0	14	5	9	0	88
4	Crackerneck Creek at Selsa Road in Independence, Mo.	--	--	--	--	--	--	--	--	--	--	--
5	Spring Branch Creek at 78 Highway in Independence, Mo.	11	15	15	4	15	10	11	7	5	4	97
6	Little Blue River near Lake City, Mo.	17	13	7	3	15	0	20	10	5	0	90
7	E. Fork Crooked River near Rich-mond, Mo.	9	9	7	2	10	13	1	3	6	2	62
8	S. Grand River below Freeman, Mo.	19	17	13	3	12	19	15	3	4	11	116
Average score		15.3	14.5	9.3	3.0	13.7	8.0	12.7	5.2	5.3	3.2	90.2

Figure 46. Degraded stream conditions at East Fork Crooked River, showing recent heavy sediment deposition and accumulation of large woody debris, September 2008.

Figure 47. Representative channel and substrate at South Grand River, September, 2008.

The sites assessed in this study were all located in downstream reaches of their basins except Little Blue River site 3. However, habitat scores measure local habitat and not the overall land use in a basin. Wilkison and others (2009) stated that in local area streams a more indicative relation existed between the amounts of urbanization upstream from a site on macroinvertebrate scores than when making comparisons with the habitat assessment score. Additionally, increased urbanization downstream resulted in increased point and non-point loads to streams that affected aquatic diversity and stream health (Wilkison and others, 2009).

Summary and Conclusions

To identify the sources of selected constituents in urban streams and better understand processes affecting water quality and their influences on the ecological condition of urban streams and the Little Blue River in Independence, Missouri, the U.S. Geological Survey in cooperation with the City of Independence Water Pollution Control Department initiated a study in June 2005. Continuous streamflow, physical properties, dissolved oxygen, chloride, metals, nutrients, suspended sediment, common organic micro-constituents (OMCs), and fecal indicator bacteria data in base-flow and stormflow samples were collected and analyzed. These data were used to characterize contaminant sources and concentrations, loads, and yields for several basins and receiving streams within Independence and their contributions to the Little Blue River, from June 2005 through December 2008. Regression models were used to estimate continuous and annual concentrations, loadings, and yields of chloride, total nitrogen (N), total phosphorus (P), suspended sediment, and *Escherichia coli* (*E. coli*) bacteria. Habitat assessments and benthic macroinvertebrate community surveys were used to establish a baseline for evaluating the ecological condition and health of streams in Independence. Measurements and estimates of constituent concentrations and fecal indicator bacteria densities indicate that potential exists for decreasing loads and concentrations of some constituents to streams, in particular nutrients, bacteria, and turbidity, associated with suspended sediment in stormflow by the continued implementation of best management practices (BMPs) to decrease sediment loads to streams.

Independence, Missouri is located in Jackson County on the eastern side of the Kansas City metropolitan area. The land use in the city is a mix of residential, commercial, industrial, and agricultural. No wastewater treatment facilities currently (2010) discharge to streams in the Little Blue River Basin nor were any effects from industrial discharges detected during this study.

Streamgages and automatic water-quality samplers were installed at five surface-water sites; Rock Creek at Kentucky Road, two sites on the Little Blue River [Little Blue River at 39th Street (upstream) and Little Blue River near Lake City (downstream)], Crackerneck Creek at Selsa Road, and Spring Branch Creek at 78 Highway. Continuous water-quality monitors (CWQMs) were installed at three of these sites; the two Little Blue River sites and Spring Branch Creek. In-stream measurements were made for streamflow, physical properties (turbidity, pH, specific conductance, and temperature), and dissolved oxygen concentration. Samples were collected and analyzed for chloride, metals, nutrients, suspended sediment, OMCs, and fecal indicator bacteria. Beginning in 2006, annual dry-weather screenings of selected streams within Independence were conducted to identify any point source discharges. Habitat assessments and benthic macroinvertebrate community surveys were conducted to establish a baseline for evaluating the ecological condition of streams in Independence.

Water-quality and environmental data were analyzed for various factors that are indicative of or can affect stream health and contaminant loads in streams. Concentrations, loads, and yields for chloride, total N, and total P, suspended sediment, and *E. coli* densities at the five sampling sites were subjected to nonparametric statistical analyses to identify differences, if any, among concentrations of constituents from different basins and between the upstream and downstream Little Blue River sites. Stream sampling sites were selected to be representative of the streams draining the developed areas of Independence that receive discharge from the municipal separate storm sewer system (MS4) and the city's contribution to the water quality of the Little Blue River. Instantaneous loads of selected constituents and OMCs in base flow and stormflow at stream sites were calculated. Daily, monthly, and annual loads were estimated for selected constituents using LOADEST, a FORTRAN-based load estimator program. *E. coli* isolated from water samples for microbial source tracking (MST) analysis were compared to a host-source library of *E. coli* deoxyribonucleic acid (DNA) patterns from three hosts: dogs, geese, and humans. The Invertebrate Data Analysis System (IDAS) software was used for processing, and computing metrics for abundance and diversity from benthic macroinvertebrate samples. A Stream Condition Index (SCI), similar to the Missouri Stream Condition Index (MSCI), was calculated from four metric indices: Total Taxa Richness (TTR), Ephemeroptera-Plecoptera-Trichoptera Richness (EPTR), Biotic Index (BI), and the Shannon Diversity Index (SDI).

Precipitation was less in water year (WY) 2006 than in 2007 and 2008. For the gaged streams draining Independence (Rock Creek, Crackerneck, and Spring Branch Creek), streamflow during WY 2006 was 23 to 34 percent of the 2007 and 2008 total annual flows for these streams and was between 15 and 20 percent for WYs 2007 and 2008 of total annual flows at the Little Blue River sites.

Average daily turbidity for the Little Blue River sites and Spring Branch Creek exceeded the U.S. Environmental Protection Agency (EPA) recommended guideline of 15.5 nephelometric turbidity units (NTU) about 40 to 60 percent of the time. The Missouri standard for the protection of aquatic life in warm-water streams (AQL) for dissolved oxygen is 5 milligrams per liter (mg/L) for streams designated as warm-water fisheries including the Little Blue River. Daily dissolved oxygen concentrations fell below the 5 mg/L standard between less than 2 percent of the time for the Little Blue River sites to about 5 percent of the time at Spring Branch Creek. The Missouri standard for AQL for water temperature of 32 2/9 degrees Celsius (°C) was exceeded less than one percent of the time for the Little Blue River sites. More frequent diurnal exceedance was recorded, but of short duration, during hot weather and at low-flow conditions at Spring Branch Creek.

Twenty-five base-flow water-quality samples were collected at the five streamgage sampling sites beginning in June 2006. Samples were collected during three seasonal periods; a spring and early summer high runoff season (March through July), a late summer and fall transitional season (August through October), and a low runoff winter season (November through February). The majority of samples were collected during the transitional season with the remainder split between winter and the spring and early summer seasons. Chloride concentrations in base flow ranged from 23.6 to 329 mg/L. Large chloride concentrations are because of residual effects from road salt carried into streams during runoff. Nutrient concentrations in base-flow samples are likely attributable to several nonpoint sources including: atmospheric deposition; decomposition of plants, yard waste, and other organic matter; leaky sewer lines; fertilizers leached from soils; and residual effects from sanitary sewer overflows (SSOs). Nutrient concentrations in base-flow samples collected for the streams draining Independence (Rock Creek, Crackerneck Creek, and Spring Branch Creek) exceeded the EPA level III, ecoregion 40, standard for total N and total P for about 90 percent of samples. Base-flow samples collected at the two Little Blue River sites exceeded the total N and total P standard less often, 30 percent of the time, likely because of nutrient loss from precipitation with sediment and biotic uptake in upstream reservoirs. Two categories of OMCs in base-flow samples had detections more than one-half the time, pesticides (100 percent) and plastics (67 percent). Most detections in base flow for OMCs were small relative to minimum reporting levels.

A total of 91 stormflow water-quality samples were collected beginning in June 2005. Chloride concentrations were not significantly different among sampling sites. Combined base-flow and stormflow measured data were used to calculate regression equations to estimate chloride loads. Smaller estimated loads for WY 2006 are largely because of lack of precipitation and runoff during the winter months. The Missouri chronic standard for AQL for chloride is 230 mg/L and the acute standard is 860 mg/L. Chloride concentrations were estimated to exceed the acute standard infrequently (less than one percent) at one site, Spring Branch Creek. The chronic standard at all sites was estimated to be exceeded more frequently, between about 2 and 30 percent of the time. Rock Creek had smaller flow-weighted concentrations for chloride than the other two streams draining Independence in WYs 2007 and 2008, but was larger in drier WY 2006.

The estimated median monthly chloride loads for all sites were smallest during the early and late summer (July through September). However, the estimated median monthly loads for the Little Blue River sites remained elevated for a longer period into the wet season, through May. The smaller streams draining Independence only showed larger monthly chloride loads through March. The modeled data indicate a larger effect from the winter application of de-icers on the smaller, unregulated, and more urban streams. Two streams draining Independence, Crackerneck Creek and Spring Branch Creek, contributed about 76 percent of the increase between sites on the Little Blue River in estimated chloride load. However, the effects of de-icers on base flow in Independence streams throughout the year are not yet known and are the subject of further study.

Concentrations of total recoverable metals in stormflow samples were largely because of transport while adsorbed with suspended sediment. For the single round of sampling for dissolved metals in stormflow, concentrations were several orders of magnitude smaller compared to total recoverable metals concentrations and none exceeded the chronic or acute standards for AQL.

Measured nutrient concentrations in stormflow samples are likely attributable to nonpoint sources, but may also have been influenced by leaky sewer pipes and storm sewer overflows (SSOs) to the streams draining Independence, in particular Rock Creek, during some larger stormflows. Median total N concentrations in stormflow were largest for Rock Creek, but were not significantly larger than the other sampled streams draining Independence or the Little Blue River sites. However, the median concentrations of total N for the three more urbanized streams draining Independence, Rock Creek, Crackerneck Creek, and Spring Branch Creek, are all larger than for the Little Blue River sites. The median total P concentrations during stormflow were largest for Spring Branch Creek. During base flow the majority of total P was found to be in the dissolved phase. However, during stormflow only about 12 percent of measured P at all sites was dissolved P, so that total P concentrations are largely attributable to particulates in suspended sediment.

Estimated daily total N and P concentrations and loads were calculated with regression equations using combined measured base-flow and stormflow data for July 2005 through December 2008. Measured nutrient concentrations in excess of the EPA proposed nutrient standard for level III ecoregion 40 streams in stormflow samples are likely attributable to nonpoint sources. Leaky sewer lines and SSOs may also contribute nutrients to Independence streams. Estimated average daily total N and total P concentrations for Rock Creek and Crackerneck Creek were greater than the EPA proposed standard (0.86 mg/L for total N and 0.09 mg/L for total P) for the entire model period, July 2005 through December 2008. Spring Branch Creek exceeded the EPA proposed standard about 86 percent of the time for total N and 95 percent of the time for total P. The Little Blue River sites exceeded the EPA proposed standard for total N between 53 and 62 percent of the time and for total P between 81 and 93 percent of the time. Settling out of total N and total P associated with particulates both in the lakes upstream and in pools within the Little Blue River most likely explains the smaller median total N concentrations in the Little Blue River compared to the streams draining Independence. Two streams draining Independence, Crackerneck Creek and Spring Branch Creek contributed about 22 percent of the increase in total N load and about 13 percent of the increase in total P load between sites on the Little Blue River. Larger relative percentage contributions occurred during lower flows in WY 2006. Rock Creek also had larger flow-weighted annual concentrations of total N, but only marginally, in WY 2006 and its annual flow-weighted concentrations for total P were intermediate between the two other sites. The estimated median monthly loads for both constituents at all sites are largest during the spring and early summer wet season.

Measured suspended sediment concentrations between stream sites were not significantly different. However, suspended sediment yields were significantly larger for the streams draining Independence than for the Little Blue River sites. Because of this, median measured suspended sediment loads in stormflow increased downstream for the Little Blue River from 2,150 to 9,300 grams per second (g/s).

Estimated daily suspended sediment concentrations and loads were calculated with regression equations for July 2005 through December 2008 for three sites; Spring Branch Creek and the two Little Blue River sites. The estimated average daily suspended sediment yield for the Little Blue River during the study period increased downstream, so that estimated annual suspended sediment loads were two to three times larger downstream with only about a 20 percent increase in total drainage area. The estimated annual suspended sediment loads for WY 2006, when precipitation was low, were about one to two orders of magnitude less than the loads estimated for WYs 2007 and 2008 for the Little Blue River sites and Spring Branch Creek. Estimated annual suspended sediment loads at the downstream Little Blue River site in WY 2006 were less than one percent of the 658,000 megagram (Mg) load in WY 2007. Remobilization of sediment stored in pools and on the floodplain of the Little Blue River during stormflow along with road and commercial construction activities in the lower portions of the Crackerneck Creek and Spring Branch Creek basins and along the Little Blue River are likely contributors to the two to three times larger loads downstream at Little Blue River for all 3 years.

Stormflow had larger median measured concentrations of OMCs, 6.82 µg/L, than base flow, 1.77 µg/L. The four categories with the most total detections had samples with detections more than 90 percent of the time; pesticides (100 percent), polyaromatic hydrocarbons (PAHs) and combustion by-products (99 percent), plastics (93 percent), and stimulants (91 percent). Most detections of OMCs were small relative to minimum reporting levels and less than 2 micrograms per liter. Rock Creek had the largest median concentration of total OMCs in stormflow, 15.6 µg/L, followed by Crackerneck Creek with 10.5 µg/L, and Spring Branch Creek with 7.86 µg/L. Larger concentrations in Rock Creek are likely because of contributions from SSOs. Median concentrations in the Little Blue River were smaller. The contributions of OMCs by Crackerneck Creek and Spring Branch Creek did not increase concentrations downstream for the Little Blue River.

From 2006 through 2008 dry-weather screening was conducted jointly by the USGS and City of Independence in all major basins and within the city limits of Independence except Fire Prairie Creek and West Fire Prairie Creek. A total of 536 samples were collected and analyzed for total chlorine, total dissolved copper, phenols, and anionic surfactants. A relatively small number (14.0 percent) of potential point source discharges were identified. Point-source discharges were identified for total chlorine, phenols, and anionic surfactants. There were 27 total chlorine detections at or in exceedance of the Missouri permitting level of 0.13 mg/L. The main source of total chlorine in streams likely comes from leaky water supply pipes, lawn watering, irrigation, or illicit discharges. The maximum total chlorine detection was 7.00 mg/L, from a residential grey-water pipe discharging directly to a stream. The only detection for phenols in exceedance of the Missouri standard for protection of aquatic life (0.100 mg/L) was a single detection greater than 0.200 mg/L. There were 51 detections of anionic surfactants equal to or exceeding an arbitrary standard of 0.028 mg/L. The maximum detected concentration for anionic surfactants was 5.000 mg/L from the same sample that also had the largest total chlorine detection.

During dry-weather screening, in addition to locating several point sources of contamination, high specific conductances, indicative of large chloride concentrations from application of road salt during the winter months, were measured in the Adair Creek Basin near Interstate 70 in April 2007 and July 2008, months after the winter road-salt application season. The highest specific conductance readings of over 4,000 microsiemens per centimeter (µS/cm) were measured in small tributaries to Adair Creek along Interstate 70. Linear regression equations using data from local area streams were used to estimate chloride concentrations of about 1,100 mg/L or greater for streams with specific conductance measured that high.

Estimated average daily *E. coli* yields were larger for the smaller urban streams than for the Little Blue River. However, the estimated annual loads were greater at the Little Blue River sites because of its larger flow volume. Estimated average daily *E. coli* densities at both Little Blue River sites exceeded the category B standard of 206 colonies per 100 milliliters (col/100 mL) about 70 percent of the time. Spring Branch Creek had the largest estimated average daily yield with 1,080 billion colonies per square kilometer (col/km^2). Higher suspended sediment concentrations in the smaller streams likely contribute to larger estimated average daily *E. coli* yields. The estimated annual *E. coli* load was larger at both Little Blue River sites than Spring Branch Creek or Rock Creek for WYs 2007 and 2008; however the estimated annual *E. coli* load was more at Spring Branch Creek than at the downstream Little Blue River site for WY 2006. Since 2006 was a dry year, this indicates a greater proportional contribution of *E. coli* loads by smaller streams such as Spring Branch Creek and Crackerneck Creek into the Little Blue River at low flows than during a year with greater precipitation and larger flows. Median instantaneous *E. coli* densities for stormflow samples showed a 21 percent increase measured at the downstream site on the Little Blue River from the upstream site. Generally, maximum estimated bacteria densities and loads for all sites occurred during the wet season months of May and June and minimum bacteria densities occurred in December and January, the period of the year that is usually the driest and runoff and water temperature lowest.

A minority of *E. coli* (0 to 27.8 percent) from samples collected in May through October 2007 were identified to be from human sources using MST methods. Samples determined to have high percentages of human host-sources are indicative of leaky sewers, SSOs, or other sources of untreated sewage. Additional MST samples from streams in Independence can improve interpretation of sources.

Benthic macroinvertebrate samples were collected from five study sites and two reference sites in the spring of 2007 and in the spring and fall of 2008. Habitat assessments were conducted in September 2008 at four study sites and two reference sites. Over the three rounds of sampling for this study 195 different taxa were identified. The majority of samples scored a rating of partially biologically supporting (PBS). No sites, including reference sites, were found to be fully biologically supporting. The Little Blue River sites had an average SCI score of 12 (PBS) and the streams draining Independence had an average SCI score of 10 (PBS). Habitat scores for the Independence sites ranged from a low of 88 out of a possible 170 for Rock Creek and the upstream Little Blue River site, to a high of 97 for Spring Branch Creek. The assessment factors having the most influence on lowering habitat scores at the four Independence sites were; high sediment deposition, channel alteration, poor bank stability, and loss or absence of bank and riparian vegetation.

This study used various analytical tools to characterize how stormflow and the MS4 affect water quality and stream health in Independence. Constituents mobilized through surface runoff to the MS4, and possibly SSOs, play a larger role in the smaller, more urbanized streams draining Independence than in the larger regulated Little Blue River. As development and population increase within the city and further alter and affect urban streams, these characterizations and ongoing studies will increase in importance.

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Tables

Table 3. Concentrations of selected water-quality constituents and organic micro-constituents in blank water samples.

[µS/cm, microsiemens per centimeter at 25 degrees Celsius; dissolved concentrations for filtered samples; mg/L, milligrams per liter; total concentrations for unfiltered samples; °C, degrees Celsius; N, nitrogen; P, phosphorus; *E. coli, Escherichia coli*; MPN/100 mL, most probable number per 100 milliliters; col/100 mL, colonies per 100 milliliters; µg/L, micrograms per liter; BDE, 2,2,'4,4'-tetrabromodiphenyl ether; DEET, N,N-Diethyl-meta-toluamide; --, no data; <, less than; E, estimated; M, presence verified not quantified]

Site number (table 1; fig. 1)	Sample start date	Sample start time	Specific conductance, laboratory (µS/cm)	Specific conductance, field (µS/cm)	Sodium, dissolved (mg/L)	Sodium, total (mg/L)	Chloride, dissolved (mg/L)	Residue on evaporation at 180 °C, dissolved (mg/L)	Ammonia plus organic nitrogen, total (mg/L as N)	Ammonia, dissolved (mg/L as N)	Nitrite plus nitrate, dissolved (mg/L as N)
3	9/27/2006	0845	2	--	<0.20	<0.5	<0.20	<10	<0.10	<0.010	<0.06
6	6/13/2005	1416	--	--	--	--	--	--	--	--	--
	8/13/2005	1300	4	--	<.20	<.5	<.20	<10	<.10	<.04	<.06
	4/8/2008	1320	2	--	<.12	<.1	<.12	<10	<.14	<.020	<.04

Site number (table 1; fig. 1)	Sample start date	Sample start time	Nitrate, dissolved (mg/L as N)	Nitrite, dissolved (mg/L as N)	Ortho-phosphate, dissolved (mg/L as P)	Phosphorus, dissolved (mg/L as P)	Phosphorus, total (mg/L as P)	*E. coli* (MPN/ 100 mL)[1]	Fecal coliform (col/100 mL)	Total coliform (MPN/100 mL)[1]	Aluminum, total (µg/L)
3	9/27/2006	0845	--	<0.002	<0.006	<0.04	<0.04	<1	<1	7	<2
6	6/13/2005	1416	--	--	--	--	--	--	--	--	--
	8/13/2005	1300	--	<.008	<.02	<.04	<.04	--	--	--	<2
	4/8/2008	1320	--	<.002	<.006	<.04	<.04	<1	0	3	<4

Site number (table 1; fig. 1)	Sample start date	Sample start time	Arsenic, total (µg/L)	Cadmium, total (µg/L)	Chromium, total (µg/L)	Copper, total (µg/L)	Cyanide (mg/L)	Lead, total (µg/L)	Mercury, total (µg/L)	Zinc, total (µg/L)	1-Methyl-naphthalene (µg/L)
3	9/27/2006	0845	<0.12	<2	<2	<4	<0.010	<0.06	<0.010	<6	<0.2
6	6/13/2005	1416	--	--	--	--	--	--	--	--	<.5
	8/13/2005	1300	<2	<2	<2	<4	<.010	<.06	<.010	<6	<.5
	4/8/2008	1320	<.60	<.01	<.40	<1.2	<.010	<.06	<.010	<2.0	<.2

Site number (table 1; fig. 1)	Sample start date	Sample start time	2,6-Dimethyl-naphthalene (µg/L)	2-Methyl-naphthalene (µg/L)	3,4-Dichlo-rophenyl isocyanate (µg/L)	3-beta-Coprostanol (µg/L)	3-Methyl-1H-indole (µg/L)	3-tert-Butyl-4-hydroxyan-isole (µg/L)	4-Cumylphenol (µg/L)	4-n-Octylphenol (µg/L)	4-Nonylphenol (all isomers) (µg/L)
3	9/27/2006	0845	<0.2	<0.2	<2.0	<3	<0.2	<0.2	<0.2	<0.2	<2
6	6/13/2005	1416	<.5	<.5	<.50	<2	<1	<5	<1	<1	<5
	8/13/2005	1300	<.5	<.5	<.50	<2	<1	<5	<1	<1	M
	4/8/2008	1320	<.2	<.2	<2.0	<.8	<.2	<.2	<.2	<.2	<2

Table 3. Concentrations of selected water-quality constituents and organic micro-constituents in blank water samples.—Continued

[µS/cm, microsiemens per centimeter at 25 degrees Celsius; dissolved concentrations for filtered samples; mg/L, milligrams per liter; total concentrations for unfiltered samples; °C, degrees Celsius; N, nitrogen; P, phosphorus; *E. coli, Escherichia coli*; MPN/100 mL, most probable number per 100 milliliters; col/100 mL, colonies per 100 milliliters; µg/L, micrograms per liter; BDE, 2,2,'4,4'-tetrabromodiphenyl ether; DEET, N,N-Diethyl-meta-toluamide; --, no data; <, less than; E, estimated; M, presence verified not quantified]

Site number (table 1; fig. 1)	Sample start date	Sample start time	Diethoxy-nonylphenol (all isomers) (µg/L)	Ethoxy-nonylphenol (all isomers) (µg/L)	Diethoxy-octylphenol (µg/L)	Ethoxy-octylphenol (µg/L)	4-tert-Octyl-phenol (µg/L)	5-Methyl-1H-benzotri-azole (µg/L)	Acetophenone (µg/L)	Acetyl hexamethyl tetrahydro naphthalene (µg/L)	Anthracene (µg/L)
3	9/27/2006	0845	<3	<2.0	<0.32	<1	<0.2	[2]<120	<0.2	<0.2	<0.2
6	6/13/2005	1416	<5	<2.0	<1	<1	<1	<2	<.5	<.5	<.5
	8/13/2005	1300	<5	<2.0	<1	<1	<1	<2	<.5	<.5	<.5
	4/8/2008	1320	<3	<2.0	<.32	<1	<.2	<2	<.3	<.2	<.2

Site number (table 1; fig. 1)	Sample start date	Sample start time	9,10-Anthra-quinone (µg/L)	Atrazine (µg/L)	BDE congener 47 (µg/L)	Benzo(a) pyrene (µg/L)	Benzo phenone (µg/L)	beta-Sitos-terol (µg/L)	beta-Stigmas-tanol (µg/L)	Bis(2-ethyl-hexyl) phthalate (µg/L)	Bisphenol A (µg/L)
3	9/27/2006	0845	<0.2	<0.20	<0.2	<0.2	<0.2	<3	<3	<3	<4
6	6/13/2005	1416	<.5	<.50	<.5	<.5	E.2	<2	<2	<2	<1
	8/13/2005	1300	<.5	<.50	<.5	<.5	E.3	<2	<2	<2	<1
	4/8/2008	1320	<.2	<.20	<.2	<.2	E.1	<2	<.8	<2	<.4

Site number (table 1; fig. 1)	Sample start date	Sample start time	Bromacil (µg/L)	Caffeine (µg/L)	Camphor (µg/L)	Carbaryl (µg/L)	Carbazole (µg/L)	Chlorpyrifos (µg/L)	Cholesterol (µg/L)	Cotinine (µg/L)	DEET (µg/L)
3	9/27/2006	0845	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<3	<0.8	<0.2
6	6/13/2005	1416	<.5	<.5	<.5	<1	<.5	<.5	<2	<1	<.5
	8/13/2005	1300	<.5	<.5	<.5	<1	<.5	<.5	<2	<1	M
	4/8/2008	1320	<.2	<.2	<.2	<.2	<.2	<.2	<.8	<.8	0.4

Site number (table 1; fig. 1)	Sample start date	Sample start time	Diazinon (µg/L)	Dichlorvos (µg/L)	Diethyl phthalate (µg/L)	d-Limonene (µg/L)	Fluoranthene (µg/L)	Hexahydro-hexamethyl cyclopenta-benzopyran (µg/L)	Indole (µg/L)	Isoborneol (µg/L)	Isophorone (µg/L)
3	9/27/2006	0845	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2
6	6/13/2005	1416	<.5	<1	<.5	<.5	<.5	<.5	<.5	<.5	<.5
	8/13/2005	1300	<.5	<1	<.5	<.5	<.5	<.5	<.5	<.5	<.5
	4/8/2008	1320	<.2	<.2	<.2	<.2	<.2	<.2	<.2	<.2	<.2

Table 3. Concentrations of selected water-quality constituents and organic micro-constituents in blank water samples.—Continued

[µS/cm, microsiemens per centimeter at 25 degrees Celsius; dissolved concentrations for filtered samples; mg/L, milligrams per liter; total concentrations for unfiltered samples; °C, degrees Celsius; N, nitrogen; P, phosphorus; *E. coli, Escherichia coli*; MPN/100 mL, most probable number per 100 milliliters; col/100 mL, colonies per 100 milliliters; µg/L, micrograms per liter; BDE, 2,2,'4,4'-tetrabromodiphenyl ether; DEET, N,N-Diethyl-meta-toluamide; --, no data; <, less than; E, estimated; M, presence verified not quantified]

Site number (table 1; fig. 1)	Sample start date	Sample start time	Isoquinoline (µg/L)	Menthol (µg/L)	Metalaxyl (µg/L)	Methyl salicylate (µg/L)	Metolachlor (µg/L)	*para*-Cresol (µg/L)	Pentachloro-phenol (µg/L)	Phenanthrene (µg/L)	Phenol (µg/L)
3	9/27/2006	0845	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.8	<0.2	<0.2
6	6/13/2005	1416	<.5	<.5	<.5	<.5	<.5	<1	<2	<.5	<.5
	8/13/2005	1300	<.5	<.5	<.5	<.5	<.5	<1	<2	<.5	<.5
	4/8/2008	1320	<.2	<.2	<.2	<.2	<.2	<.2	<.8	<.2	<.2

Site number (table 1; fig. 1)	Sample start date	Sample start time	Prometon (µg/L)	Pyrene (µg/L)	Tributyl phosphate (µg/L)	Triclosan (µg/L)	Triethyl citrate (µg/L)	Triphenyl phosphate (µg/L)	Tris(2-butoxy-ethyl) phosphate (µg/L)	Tris(2-chloro-ethyl) phosphate (µg/L)	Tris (dichloroisopropyl) phosphate (µg/L)
3	9/27/2006	0845	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.6	<0.2	<0.2
6	6/13/2005	1416	<.5	<.5	<.5	<1	<.5	<.5	<.5	<.5	<.5
	8/13/2005	1300	<.5	<.5	<.5	<1	<.5	<.5	<.5	<.5	<.5
	4/8/2008	1320	<.2	<.2	M	<.2	<.2	<.2	E.3	<.2	<.2

Site number (table 1; fig. 1)	Sample start date	Sample start time	1,4-Dichloro-benzene (µg/L)	Tribromo-methane (µg/L)	Isopropyl-benzene (µg/L)	Naphthalene (µg/L)	Tetrachloro-ethene (µg/L)
3	9/27/2006	0845	<0.2	<0.2	<0.2	<0.2	<0.4
6	6/13/2005	1416	<.5	<.5	<.5	E.1	<.5
	8/13/2005	1300	<.5	<.5	<.5	E.1	<.5
	4/8/2008	1320	<.2	<.2	<.2	<.2	<.4

[1]For the purposes of this report, MPN is considered to be comparable to colonies per 100 milliliters.

[2]Analyzing laboratory raised the reporting level due to a sample preparation error specific to this analyte.

Table 4. Annual deposition rates of selected constituents in precipitation at five midwestern monitoring sites in Iowa, Kansas, Missouri, and Nebraska, 2005 through 2008.

[Data from the National Atmospheric Deposition Program, 2009; ID, identification number; kg/km²; kilograms per square kilometer; H+, hydrogen ion; cm, centimeter; in., inch; --, not available]

Site ID[1]	Year	Calcium (kg/km²)	Magnesium (kg/km²)	Potassium (kg/km²)	Sodium (kg/km²)	Ammonia (kg/km²)	Nitrate (kg/km²)	Inorganic nitrogen (kg/km²)	Total nitrogen[2] (kg/km²)	Chloride (kg/km²)	Sulfate (kg/km²)	H+ (kg/km²)	pH (standard units)	Precipitation (cm)	Precipitation (in.)
Iowa (IA23)	2005	307	22.9	22.9	42.9	357	823	463	1,643	65	892	2	5.52	74.0	29.12
	2006	330	26.6	18.3	39.5	422	937	540	1,899	62	922	3	5.36	76.1	29.94
	2007	401	35.4	41.8	76.1	556	1,160	695	2,411	117	1,091	4	5.45	107.2	42.20
	2008	407	36.9	38.2	70	505	1,086	638	2,229	100	1,158	4	5.52	127.2	50.08
Kansas (KS07)	2005	267	19.7	21.4	61.7	339	1,012	492	1,843	95	1,066	9	4.98	85.7	33.75
	2006	329	21.7	25.7	50.6	353	948	488	1,789	80	852	4	5.29	80.3	31.62
	2007	311	27.4	30.2	109.5	458	1,226	633	2,317	169	1,301	10	5.17	144.0	56.71
	2008	349	31.6	30.1	133.9	405	1,017	544	1,966	188	1,226	8	5.27	150.4	59.23
Kansas (KS31)	2005	323	22.8	21.9	60.2	421	1,057	566	2,044	84	1,093	5	5.27	91.2	35.91
	2006	326	22.3	18.7	46.7	340	933	475	1,748	74	788	3	5.35	71.9	28.31
	2007	343	28.7	24.7	86.9	411	998	545	1,954	128	925	4	5.42	98.8	38.90
	2008	476	34.8	28.1	82	441	973	563	1,977	113	955	4	5.46	112.3	44.22
Missouri (MO03)	2005	315	37.1	43.9	70.9	446	1,137	603	2,186	106	1,340	10	5.04	112.5	44.30
	2006	273	30.8	38.9	56.7	336	943	474	1,753	90	1,076	9	4.95	81.0	31.91
	2007	197	26.9	40	74.7	258	753	370	1,381	105	797	5	5.17	77.0	30.30
	2008	424	43.2	46.3	120.4	509	1,337	698	2,544	179	1,594	11	5.16	154.3	60.76
Nebraska (NE15)	2005	261	19.4	18.2	32.5	465	796	542	1,803	44	745	1	5.88	56.9	22.42
	2006	294	21.6	20	41.6	558	946	648	2,152	64	855	1	5.78	77.1	30.34
	2007	285	22.8	28.3	50.2	608	965	691	2,264	70	956	1	5.82	91.2	35.91
	2008	369	31.5	28.5	47.2	582	908	658	2,148	67	921	3	5.59	98.3	38.72
Maximum		476	43.2	46.3	133.9	608	1,337	698	2,544	188	1,594	11	5.88	154.3	60.76
Minimum		197	19.4	18.2	32.5	258	753	370	1,381	44	745	1	4.95	56.9	22.42
Average		329	28.2	29.3	67.7	439	998	566	2,003	100	1,028	5	--	98.4	38.73

[1]National Atmospheric Deposition Program site identification number. Site locations and data available online at *http://nadp.sws.uiuc.edu/sites/ntnmap.asp?*

[2]Total nitrogen equals ammonia plus nitrate plus inorganic nitrogen.

Table 5. Summary statistics of continuous water-quality monitor computed average daily values at three sites in Independence, Missouri, July 2005 through December 2008.

[NTU, nephelometric turbidity units; mg/L, milligrams per liter; µS/cm, microsiemens per centimeter at 25 degrees Celsius; °C, degrees Celsius]

Statistic	Turbidity (NTU)			Dissolved oxygen (mg/L)			pH (standard units)			Specific conductance (µS/cm)			Water temperature (°C)		
Site number (table 1; fig. 1)	3	5	6	3	5	6	3	5	6	3	5	6	3	5	6
							2005[1]								
Count[2]	140	155	159	144	154	142	163	168	170	161	166	171	163	168	171
Percent[3]	80.9	89.6	91.9	83.2	89.0	82.1	94.2	97.1	98.3	93.1	96.0	98.8	94.2	97.1	98.8
Minimum[4]	4.4	2.2	4.7	1.2	1.5	5.6	7.2	7.4	7.4	308	285	239	.1	.1	.4
Maximum[4]	660	350	490	16.8	15.7	15.7	8.1	8.2	8.2	973	1,860	1,100	30.6	28.9	31.3
Average[4]	29	32	34	9.8	9.2	10.0	7.8	7.9	7.9	471	735	472	15.9	14.5	16.5
Median[4]	14	9.9	16	9.1	8.5	9.6	7.8	7.8	7.9	434	726	459	16.6	14.9	17.7
							2006								
Count[2]	351	340	332	345	328	343	365	365	365	355	365	365	365	365	365
Percent[3]	96.2	93.2	91.0	94.5	89.9	94.0	100	100	100	97.3	100	100	100	100	100
Minimum[4]	4.1	3.3	5.0	4.9	2.2	4.7	7.4	7.5	7.5	273	330	268	.6	.1	.5
Maximum[4]	300	500	610	16.8	18.7	15.1	8.2	8.2	8.2	1,120	2,170	1,220	31.6	31.7	32.2
Average[4]	26	34	31	9.4	9.2	9.5	7.8	7.8	7.9	508	754	527	15.1	13.9	15.3
Median[4]	19	14	22	8.8	8.5	8.8	7.8	7.8	7.9	479	754	503	15.5	14.0	15.9
							2007								
Count[2]	321	276	291	304	280	312	364	311	328	346	344	330	356	348	330
Percent[3]	87.9	75.6	79.7	83.3	76.7	85.5	99.7	85.2	89.9	94.8	94.2	90.4	97.5	95.3	90.4
Minimum[4]	4.3	2.7	4.9	4.5	2.2	3.9	7.4	7.4	7.0	299	309	260	0	-.1	0
Maximum[4]	480	390	970	17.8	18.0	15.7	8.3	8.3	8.2	1,540	3,410	1,600	30.8	28.9	30.6
Average[4]	32	36	55	9.4	9.1	9.9	7.8	7.9	7.9	578	923	590	15.3	13.6	14.2
Median[4]	18	14	22	8.0	8.4	9.2	7.8	7.9	7.9	500	816	503	16.8	15.7	15.6

Table 5. Summary statistics of continuous water-quality monitor computed average daily values at three sites in Independence, Missouri, July 2005 through December 2008.—Continued

[NTU, nephelometric turbidity units; mg/L, milligrams per liter; µS/cm, microsiemens per centimeter at 25 degrees Celsius; °C, degrees Celsius]

Statistic	Turbidity (NTU)			Dissolved oxygen (mg/L)			pH (standard units)			Specific conductance (µS/cm)			Water temperature (°C)		
Site number (table 1; fig. 1)	3	5	6	3	5	6	3	5	6	3	5	6	3	5	6
2008															
Count[2]	263	[5]305	343	319	[5]306	363	284	[5]310	363	353	358	363	353	357	364
Percent[3]	71.9	96.2	93.7	87.2	96.5	99.2	77.6	97.8	99.2	96.4	97.8	99.2	96.4	97.5	99.5
Minimum[4]	4.1	3.1	4.1	5.6	5.3	5.6	7.5	7.6	7.5	319	316	222	.1	-.1	-.2
Maximum[4]	540	570	700	15.1	14.8	15.0	8.2	8.4	8.3	1,040	2,510	1,270	30.1	26.7	30.0
Average[4]	46	42	55	10.0	9.6	10.1	7.9	8.0	7.9	501	826	525	13.6	11.9	13.7
Median[4]	20	13	21	9.4	8.6	9.6	7.9	8.0	7.9	473	783	497	14.0	12.4	14.3

[1]Partial year. Site records begin July 14, 2005.

[2]Number of daily values recorded for the specified year.

[3]Percentage of total possible daily values recorded for the specified year.

[4]Minimum, maximum, average, and median values are calculated from data that may contain values that are estimated.

[5]Property discontinued November 2008.

Table 6. Summary of physical properties, constituent concentrations, and instantaneous loads and yields of selected constituents in base-flow samples, June 2006 through December 2008.

[ft^3/s, cubic feet per second; NTU, nephelometric turbidity units; mg/L, milligrams per liter; µS/cm, microsiemens per centimeter at 25 degrees Celsius; °C, degrees Celsius; dissolved concentrations for filtered samples; total concentrations for unfiltered samples; N, nitrogen; P, phosphorus; BOD_5, biological oxygen demand, 5 days at 20 °C; COD, chemical oxygen demand; *E. coli, Escherichia coli*, MPN/100 mL, most probable number per 100 milliliters; col/100 mL, colonies per 100 milliliters; µg/L, micrograms per liter; g/s, grams per second; col/s, colonies per second; kg/d/km^2, kilograms per day per square kilometer; RL, reporting level for streamflow, physical properties, BOD_5, COD, bacteria, and suspended sediment; LRL, laboratory reporting level for chloride, residue on evaporation, nutrients, and metals; MRL, minimum reporting level for cyanide; --, no data]

Site number (table 1; fig. 1)	Statistic	Streamflow[1] (ft^3/s)	Instantaneous streamflow[2] (ft^3/s)	Turbidity (NTU)	Dissolved oxygen (mg/L)	pH (standard units)	Specific conductance, field (µS/cm)	Water temperature (°C)	Chloride, dissolved (mg/L)	Residue on evaporation at 180 °C, dissolved (mg/L)	Ammonia plus organic nitrogen, total (mg/L as N)	Ammonia, dissolved (mg/L as N)
All	Detections	17	26	14	17	25	25	25	25	25	25	20
	Minimum[8]	0.2	0.1	7.0	5.1	7.2	382	0.7	23.6	207	0.2	0.02
	Maximum[8]	106	104	35	14.3	8.1	1,720	30.5	329	981	.8	.14
	Average[8]	11.8	15.6	16	8.3	7.8	776	19.0	85.4	455	.4	.05
	Median[8]	1.7	2.5	16	7.7	7.8	749	21.0	54.4	451	.4	.04
	RL, LRL, or MRL	.1	.1	1	0.1	0.1	1	.1	0.12	10	.1	.02
1	Detections	3	5	--	[9]1	5	5	4	5	5	5	4
	Minimum[8]	.4	.3	--	5.5	7.2	694	19.9	49.3	440	.2	.03
	Maximum[8]	1.5	2.7	--	--	7.9	1,510	22.5	265	852	.5	.12
	Average[8]	1.0	1.4	--	--	7.6	899	20.9	95.9	556	.3	.06
	Median[8]	1.0	1.1	--	--	7.7	749	20.6	54.4	475	.3	.05
3	Detections	3	5	5	5	5	5	5	5	5	5	5
	Minimum[8]	8.1	8.5	15	5.5	7.5	398	2.6	33.9	233	.4	.02
	Maximum[8]	19.0	89.0	25	12.6	7.9	873	28.5	122	458	.5	.05
	Average[8]	12.0	32.6	21	8.0	7.8	558	19.1	58.0	312	.4	.04
	Median[8]	8.8	19.0	21	7.5	7.8	492	21.4	43.2	277	.4	.04
4	Detections	4	5	--	[9]1	5	5	4	5	5	5	5
	Minimum[8]	.3	.2	--	7.7	7.3	430	18.8	23.6	263	.3	.02
	Maximum[8]	2.3	2.3	--	--	7.9	1,620	30.5	294	894	.8	.14
	Average[8]	1.1	1.2	--	--	7.7	876	24.9	98.6	508	.5	.08
	Median[8]	1.0	1.4	--	--	7.8	768	25.1	58.6	451	.4	.10
5	Detections	3	7	5	5	5	5	7	5	5	5	3
	Minimum[8]	.2	.1	7.0	5.1	7.8	710	.7	45.3	391	.2	.02
	Maximum[8]	1.7	16.0	10	13.3	8.1	1,720	29.5	329	981	.4	.07
	Average[8]	.7	5.5	8.6	8.8	7.9	987	14.3	111	588	.3	.04
	Median[8]	.3	1.7	9.0	8.7	7.9	849	18.4	58.2	529	.2	.03
6	Detections	4	4	4	5	5	5	5	5	5	5	3
	Minimum[8]	9.2	9.6	13	5.9	7.8	382	1.0	28.4	207	.4	.03
	Maximum[8]	106	104	35	14.3	8.0	1,070	29.5	188	585	.4	.05
	Average[8]	38.8	47.7	21	8.6	7.9	561	19.4	63.8	311	.4	.04
	Median[8]	20.0	38.5	17	7.6	7.9	428	21.9	34.6	248	.4	.04

Table 6. Summary of physical properties, constituent concentrations, and instantaneous loads and yields of selected constituents in base-flow samples, June 2006 through December 2008.—Continued

[ft³/s, cubic feet per second; NTU, nephelometric turbidity units; mg/L, milligrams per liter; µS/cm, microsiemens per centimeter at 25 degrees Celsius; °C, degrees Celsius; dissolved concentrations for filtered samples; total concentrations for unfiltered samples; N, nitrogen; P, phosphorus; BOD_5, biological oxygen demand, 5 days at 20 °C; COD, chemical oxygen demand; *E. coli*, *Escherichia coli*, MPN/100 mL, most probable number per 100 milliliters; col/100 mL, colonies per 100 milliliters; µg/L, micrograms per liter; g/s, grams per second; col/s, colonies per second; kg/d/km², kilograms per day per square kilometer; RL, reporting level for streamflow, physical properties, BOD_5, COD, bacteria, and suspended sediment; LRL, laboratory reporting level for chloride, residue on evaporation, nutrients, and metals; MRL, minimum reporting level for cyanide; --, no data]

Site number (table 1; fig. 1)	Statistic	Nitrite plus nitrate, dissolved (mg/L as N)	Nitrate, dissolved (mg/L as N)	Nitrite, dissolved (mg/L as N)	Total organic nitrogen (mg/L)	Total nitrogen[3] (mg/L)	Ortho-phosphate, dissolved (mg/L as P)	Phosphorus, dissolved (mg/L as P)	Phosphorus, total (mg/L as P)	Total BOD_5[4] (mg/L)	Total COD[4] (mg/L)	*E. coli* (MPN/100 mL)[5]	Fecal coliform (col/100 mL)
All	Detections	25	25	25	25	25	25	25	25	22	25	25	25
	Minimum[8]	0.06	0.05	0.003	0.2	0.5	0.008	0.010	0.060	0.2	1	41	75
	Maximum[8]	1.57	1.54	.042	.6	1.9	.165	.170	.237	2.2	17	4,000	2,600
	Average[8]	.72	.71	.013	.3	1.1	.070	.070	.114	1.0	10	582	531
	Median[8]	.60	.59	.008	.3	1.0	.067	.060	.098	1.2	10	350	230
	RL, LRL, or MRL	.04	.04	.002	.1	.1	.008	.04	.04	.1	1	1	1
1	Detections	5	5	5	5	5	5	5	5	5	5	5	5
	Minimum[8]	1.16	1.16	.004	.2	1.4	.067	.050	.098	.5	5	41	75
	Maximum[8]	1.49	1.47	.034	.4	1.8	.165	.170	.237	1.7	15	4,000	2,600
	Average[8]	1.34	1.32	.019	.3	1.7	.116	.112	.155	1.0	10	1,270	1,050
	Median[8]	1.32	1.30	.020	.2	1.7	.116	.110	.140	.8	12	770	1,000
3	Detections	5	5	5	5	5	5	5	5	4	5	5	5
	Minimum[8]	.06	.05	.003	.3	.5	.008	.010	.060	.5	5	57	140
	Maximum[8]	.42	.41	.008	.5	.9	.041	.050	.097	1.3	17	350	230
	Average[8]	.19	.19	.006	.4	.6	.029	.034	.078	1.1	10	178	168
	Median[8]	.15	.14	.006	.4	.5	.035	.040	.071	1.3	7	130	150
4	Detections	5	5	5	5	5	5	5	5	4	5	5	5
	Minimum[8]	.39	.37	.007	.3	1.0	.027	.010	.072	.7	10	190	230
	Maximum[8]	1.57	1.54	.042	.6	1.9	.122	.130	.207	2.2	13	1,100	1,100
	Average[8]	1.05	1.02	.026	.4	1.5	.081	.080	.132	1.3	12	662	738
	Median[8]	1.28	1.27	.024	.3	1.7	.077	.080	.112	1.2	12	690	870
5	Detections	5	5	5	5	5	5	5	5	4	5	5	5
	Minimum[8]	.13	.11	.004	.2	.5	.048	.030	.064	.2	3	180	180
	Maximum[8]	1.03	1.03	.011	.4	1.3	.117	.120	.146	1.3	11	1,100	940
	Average[8]	.70	.69	.006	.3	1.0	.089	.088	.119	.8	9	620	534
	Median[8]	.79	.78	.006	.2	1.0	.096	.100	.139	.9	9	510	560
6	Detections	5	5	5	5	5	5	5	5	5	5	5	5
	Minimum[8]	.08	.08	.003	.3	.5	.020	.020	.072	.5	1	83	110
	Maximum[8]	.60	.59	.011	.4	1.0	.044	.060	.096	1.5	16	310	220
	Average[8]	.33	.32	.008	.4	.7	.034	.036	.083	1.0	9	187	164
	Median[8]	.34	.33	.008	.4	.7	.038	.030	.083	1.1	9	130	150

Table 6. Summary of physical properties, constituent concentrations, and instantaneous loads and yields of selected constituents in base-flow samples, June 2006 through December 2008.—Continued

[ft^3/s, cubic feet per second; NTU, nephelometric turbidity units; mg/L, milligrams per liter; µS/cm, microsiemens per centimeter at 25 degrees Celsius; °C, degrees Celsius; dissolved concentrations for filtered samples; total concentrations for unfiltered samples; N, nitrogen; P, phosphorus; BOD_5, biological oxygen demand, 5 days at 20 °C; COD, chemical oxygen demand; *E. coli, Escherichia coli*, MPN/100 mL, most probable number per 100 milliliters; col/100 mL, colonies per 100 milliliters; µg/L, micrograms per liter; g/s, grams per second; col/s, colonies per second; kg/d/km^2, kilograms per day per square kilometer; RL, reporting level for streamflow, physical properties, BOD_5, COD, bacteria, and suspended sediment; LRL, laboratory reporting level for chloride, residue on evaporation, nutrients, and metals; MRL, minimum reporting level for cyanide; --, no data]

Site number (table 1; fig. 1)	Statistic	Total coliform (MPN/100 mL)[5]	Aluminum, total (µg/L)	Arsenic, total (µg/L)	Cadmium, total (µg/L)	Chromium, total (µg/L)	Copper, total (µg/L)	Cyanide (mg/L)	Lead, total (µg/L)	Mercury, total (µg/L)	Zinc, total (µg/L)	Suspended sediment (mg/L)	Load[6] chloride (g/s)	Load[6] nitrate (g/s as N)
All	Detections	25	25	25	11	22	10	1	25	3	21	24	25	25
	Minimum[8]	6,300	27	1.4	0.03	0.5	1.29	0.010	0.2	0.006	3.7	10	0.2	0
	Maximum[8]	190,000	716	4.7	112	1.0	2.52	--	3.5	.007	13.8	138	256	0.80
	Average[8]	42,900	342	2.4	10.2	.8	1.70	--	1.0	.006	6.2	52	29.0	.13
	Median[8]	30,000	317	2.1	.06	.9	1.49	--	.8	.006	5.8	38	7.7	.05
	RL, LRL, or MRL	1	6	0.20	.06	.4	4	.010	.1	.01	2	1	--	--
1	Detections	5	5	5	2	5	2	1	5	1	5	4	5	5
	Minimum[8]	13,000	27	1.5	.06	.5	1.67	.010	.2	.006	4.0	17	.4	.01
	Maximum[8]	120,000	460	3.9	.08	1.0	2.52	--	3.5	--	13.8	138	8.3	.11
	Average[8]	46,400	228	2.5	.07	.8	2.10	--	1.8	--	8.1	87	3.5	.05
	Median[8]	28,000	144	2.3	.07	.9	2.10	--	1.0	--	6.5	97	2.3	.04
3	Detections	5	5	5	2	4	2	0	5	1	5	5	5	5
	Minimum[8]	9,800	388	1.5	.03	.6	1.39	--	.8	.007	3.7	25	10.2	.01
	Maximum[8]	43,000	716	2.4	.07	1.0	2.09	--	1.5	--	8.1	50	128	.43
	Average[8]	22,200	543	2.0	.05	.9	1.74	--	1.0	--	6.2	36	51.9	.16
	Median[8]	18,000	558	2.1	.05	1.0	1.74	--	1.0	--	7.0	33	23.2	.15
4	Detections	5	5	5	2	5	2	0	5	0	4	5	5	5
	Minimum[8]	11,000	208	1.8	.06	.5	1.29	--	.5	--	4.9	26	.2	0
	Maximum[8]	190,000	426	4.7	.09	1.0	1.53	--	1.2	--	8.0	78	11.7	.10
	Average[8]	69,000	306	3.2	.08	.8	1.41	--	.7	--	6.7	57	3.8	.05
	Median[8]	40,000	316	2.6	.08	.8	1.41	--	.7	--	6.9	68	2.8	.05
5	Detections	5	5	5	3	4	2	0	5	0	3	5	5	5
	Minimum[8]	26,000	127	1.4	.05	.5	1.29	--	.4	--	4.1	10	.2	0
	Maximum[8]	120,000	293	3.1	112	1.0	1.35	--	.6	--	5.0	132	14.9	.08
	Average[8]	55,800	197	2.1	37.4	.8	1.32	--	.5	--	4.5	59	4.7	.03
	Median[8]	38,000	212	2.0	.08	.8	1.32	--	.5	--	4.5	52	2.2	.04
6	Detections	5	5	5	2	4	2	0	5	1	4	5	5	5
	Minimum[8]	6,300	298	1.6	.04	.6	1.45	--	.6	.006	3.7	18	7.7	.02
	Maximum[8]	37,000	577	2.5	.06	1.0	2.38	--	1.1	--	6.0	37	256	.80
	Average[8]	21,100	437	2.1	.05	.8	1.92	--	0.8	--	4.9	29	81.1	.36
	Median[8]	14,000	386	2.1	.05	.8	1.92	--	0.8	--	4.9	35	31.2	.36

Table 6. Summary of physical properties, constituent concentrations, and instantaneous loads and yields of selected constituents in base-flow samples, June 2006 through December 2008.—Continued

[ft^3/s, cubic feet per second; NTU, nephelometric turbidity units; mg/L, milligrams per liter; µS/cm, microsiemens per centimeter at 25 degrees Celsius; °C, degrees Celsius; dissolved concentrations for filtered samples; total concentrations for unfiltered samples; N, nitrogen; P, phosphorus; BOD_5, biological oxygen demand, 5 days at 20 °C; COD, chemical oxygen demand; *E. coli*, *Escherichia coli*, MPN/100 mL, most probable number per 100 milliliters; col/100 mL, colonies per 100 milliliters; µg/L, micrograms per liter; g/s, grams per second; col/s, colonies per second; $kg/d/km^2$, kilograms per day per square kilometer; RL, reporting level for streamflow, physical properties, BOD_5, COD, bacteria, and suspended sediment; LRL, laboratory reporting level for chloride, residue on evaporation, nutrients, and metals; MRL, minimum reporting level for cyanide; --, no data]

Site number (table 1; fig. 1)	Statistic	Load[6] total organic nitrogen (g/s)	Load[6] total nitrogen (g/s)	Load[6] phosphorus, total (g/s as P)	Load[6] *E. coli* (1,000 col/s)	Load[6] suspended sediment (g/s)	Yield[7] chloride ($kg/d/km^2$)	Yield[7] nitrate ($kg/d/km^2$ as N)	Yield[7] total organic nitrogen ($kg/d/km^2$)	Yield[7] total nitrogen ($kg/d/km^2$)	Yield[7] phosphorus, total ($kg/d/km^2$ as P)	Yield[7] suspended sediment ($kg/d/km^2$)
All	Detections	25	25	25	25	24	25	25	25	25	25	24
	Minimum[8]	0	0	0	12	0.1	0.60	0.003	0.003	0.005	0.001	0.37
	Maximum[8]	1.13	1.74	0.212	7,060	75.6	77.8	1.69	.238	.826	.049	30
	Average[8]	0.17	0.31	.033	1,110	13.5	15.9	.344	.060	.209	.018	9.1
	Median[8]	.02	.10	.008	343	5.8	7.4	.094	.036	.163	.014	5.28
	RL, LRL, or MRL	--	--	--	--	--	--	--	--	--	--	--
1	Detections	5	5	5	5	4	5	5	5	5	5	4
	Minimum[8]	0	.02	.002	13	1.3	1.6	.042	.013	.059	.008	4.66
	Maximum[8]	.01	.13	.010	1,810	6.3	29.6	1.04	.054	.466	.037	22.4
	Average[8]	.01	.06	.005	512	3.4	12.4	.475	.033	.229	.020	12.2
	Median[8]	.01	.05	.004	321	3.0	8.1	.405	.027	.190	.016	10.8
3	Detections	5	5	5	5	5	5	5	5	5	5	5
	Minimum[8]	.09	.11	.019	137	6.8	2.1	.007	.019	.024	.004	1.43
	Maximum[8]	1.13	1.29	.151	7,060	75.6	26.8	.233	.238	.270	.032	15.9
	Average[8]	.40	.57	.063	2,320	30.4	10.9	.084	.083	.120	.013	6.38
	Median[8]	.24	.39	.050	382	23.1	4.9	.079	.050	.081	.010	4.85
4	Detections	5	5	5	5	5.0	5	5	5	5	5	5
	Minimum[8]	0	.01	.001	12	.2	1.2	.047	.020	.043	.007	1.33
	Maximum[8]	.02	.12	.007	716	4.4	77.8	1.69	.139	.826	.049	29.5
	Average[8]	.01	.06	.004	274	2.0	25.3	.787	.076	.398	.024	13.6
	Median[8]	.01	.07	.003	246	1.5	18.8	.870	.079	.450	.019	10.1
5	Detections	5	5	5	5	5	5	5	5	5	5	5
	Minimum[8]	0	0	.000	12	.1	.60	.003	.003	.005	.001	.37
	Maximum[8]	.02	.10	.014	1,120	6.4	53.5	.701	.073	.347	.048	22
	Average[8]	.01	.04	.005	334	2.7	16.6	.310	.031	.153	.017	9.2
	Median[8]	.01	.05	.003	82	1.4	7.4	.341	.034	.163	.010	5.2

Table 6. Summary of physical properties, constituent concentrations, and instantaneous loads and yields of selected constituents in base-flow samples, June 2006 through December 2008.—Continued

[ft^3/s, cubic feet per second; NTU, nephelometric turbidity units; mg/L, milligrams per liter; µS/cm, microsiemens per centimeter at 25 degrees Celsius; °C, degrees Celsius; dissolved concentrations for filtered samples; total concentrations for unfiltered samples; N, nitrogen; P, phosphorus; BOD_5, biological oxygen demand, 5 days at 20 °C; COD, chemical oxygen demand; *E. coli, Escherichia coli*, MPN/100 mL, most probable number per 100 milliliters; col/100 mL, colonies per 100 milliliters; µg/L, micrograms per liter; g/s, grams per second; col/s, colonies per second; $kg/d/km^2$, kilograms per day per square kilometer; RL, reporting level for streamflow, physical properties, BOD_5, COD, bacteria, and suspended sediment; LRL, laboratory reporting level for chloride, residue on evaporation, nutrients, and metals; MRL, minimum reporting level for cyanide; --, no data]

Site number (table 1; fig. 1)	Statistic	Load[6] total organic nitrogen (g/s)	Load[6] total nitrogen (g/s)	Load[6] phosphorus, total (g/s as P)	Load[6] *E. coli* (1,000 col/s)	Load[6] suspended sediment (g/s)	Yield[7] chloride ($kg/d/km^2$)	Yield[7] nitrate ($kg/d/km^2$ as N)	Yield[7] total organic nitrogen ($kg/d/km^2$)	Yield[7] total nitrogen ($kg/d/km^2$)	Yield[7] phosphorus, total ($kg/d/km^2$ as P)	Yield[7] suspended sediment ($kg/d/km^2$)
6	Detections	5	5	5	5	5	5	5	5	5	5	5
	Minimum[8]	.09	.16	.024	259	9.5	1.4	.004	.016	.029	.004	1.68
	Maximum[8]	1.12	1.74	.212	3,940	58.9	45.1	.142	.198	.307	.037	10.4
	Average[8]	.44	.83	.089	2,130	27.0	14.3	.064	.077	.147	.016	4.76
	Median[8]	.31	.71	.079	2,550	24.5	5.5	.064	.055	.125	.014	4.32

[1]Streamflow measured at time of sampling used in calculations of loads and yields.

[2]Streamflow calculated from an established stage-discharge relation for the site at the time of sampling.

[3]Total nitrogen equals ammonia plus nitrate plus nitrite plus organic nitrogen.

[4]Analyses and reported results from the laboratory at the City of Independence Rock Creek Wastewater Teatment Plant.

[5]For the purposes of this report, most probable number per 100 milliliters is considered to be comparable to colonies per 100 milliliters

[6]Loads are instantaneous loads calculated from multiplying the instantaneous streamflow, sampled concentration, and a constant to standardize units.

[7]Yields are instantaneous yields calculated by dividing the instantaneous load by the drainage area above the sample collection point and multiplying by a constant to standardize units.

[8]Minimum, maximum, average, and median values are calculated from data that may contain values that are estimated or less than the method detection level.

[9]Only one field measurement for dissolved oxygen was made for samples collected during base flow at these sites.

Table 7. Summary of constituent concentrations by category and instantaneous loads of total common organic micro-constituents by site in base-flow samples, June 2006 through December 2008.

[µg/L, micrograms per liter; PAHs, polyaromatic hydrocarbons; OMC, common organic micro-constituents; ft^3/s, cubic feet per second; mg/s, milligrams per second; --, no data]

Site number (table 1; fig. 1)	Statistic	Total anti-oxidants (µg/L)	Total detergents (µg/L)	Total disinfectants (µg/L)	Total fire retardants (µg/L)	Total flavorings and fragrances (µg/L)	Total PAHs and combustion products (µg/L)	Total pesticides (µg/L)	Total plastics (µg/L)	Total solvents (µg/L)	Total sterols and stanols (µg/L)	Total stimulents (µg/L)	Total OMC (µg/L)	Instant-aneous stream-flow[1] (ft^3/s)	Instant-aneous load total OMC (mg/s)
All	Detections[2]	2	7	4	10	6	10	24	16	3	11	6	24	--	--
	Total detections[3]	2	9	4	14	8	30	87	22	3	18	8	205	--	--
	Minimum[4]	0.38	0.13	0.02	0	0.01	0.02	0.06	0.02	0.004	0.32	0.06	0.13	0.1	0.01
	Maximum[4]	.60	1.66	.14	0.14	.14	.20	54.13	2.38	.01	6.37	.46	60.64	104	4.67
	Average[4]	.49	.61	.07	.05	.04	.09	3.45	.54	.01	1.44	.16	4.82	16.0	.77
	Median[4]	.49	.37	.06	.04	.02	.08	0.59	.18	.01	.75	.09	1.77	2.5	.15
1	Detections[2]	0	2	2	1	2	3	4	4	1	2	2	4	--	--
	Minimum[4]	--	.52	.02	.04	.02	.10	.06	.12	.004	0.34	.06	.14	.3	.01
	Maximum[4]	--	1.04	.14	--	.14	.20	3.10	2.38	--	1.79	.11	5.56	2.7	.25
	Average[4]	--	.78	.08	--	.08	.13	1.54	.96	--	1.06	.08	3.23	1.4	.09
	Median[4]	--	.78	.08	--	.08	.11	2.01	.67	--	1.06	.08	2.81	1.1	.07
3	Detections[2]	0	2	0	2	1	3	5	4	1	2	1	5	--	--
	Minimum[4]	--	.13	--	.02	.01	.03	.38	.02	.01	1.08	.06	.77	8.5	.21
	Maximum[4]	--	.37	--	.11	--	.10	5.08	1.80	--	1.82	--	7.12	89.0	4.67
	Average[4]	--	.25	--	.06	--	.06	1.43	.50	--	1.45	--	2.59	32.6	1.89
	Median[4]	--	.25	--	.06	--	.06	.41	.09	--	1.45	--	1.85	19.0	1.71
4	Detections[2]	1	2	1	3	2	3	5	4	0	2	1	5	--	--
	Minimum[4]	.38	.21	.08	.05	.01	.02	.08	.08	--	.48	.22	.13	.2	.01
	Maximum[4]	--	1.66	--	.14	.02	.07	54.13	1.29	--	6.37	--	60.64	2.3	.39
	Average[4]	--	.93	--	.09	.02	.05	11.38	.51	--	3.43	--	13.76	1.2	.12
	Median[4]	--	.93	--	.07	.02	.06	1.25	.34	--	3.43	--	1.69	1.4	.06
5	Detections[2]	0	0	1	2	1	0	4	1	0	3	1	4	--	--
	Minimum[4]	--	--	.03	.02	.01	--	.12	.19	--	0.41	.06	0.81	.1	.01
	Maximum[4]	--	--	--	.04	--	--	2.95	--	--	1.79	--	4.75	3.6	.08
	Average[4]	--	--	--	.03	--	--	1.18	--	--	.95	--	1.98	1.4	.04
	Median[4]	--	--	--	.03	--	--	.82	--	--	.66	--	1.17	1.0	.04

Table 7. Summary of constituent concentrations by category and instantaneous loads of total common organic micro-constituents by site in base-flow samples, June 2006 through December 2008.—Continued

[µg/L, micrograms per liter; PAHs, polyaromatic hydrocarbons; OMC, common organic micro-constituents; ft^3/s, cubic feet per second; mg/s, milligrams per second; --, no data]

Site number (table 1; fig. 1)	Statistic	Total anti-oxidants (µg/L)	Total detergents (µg/L)	Total disinfectants (µg/L)	Total fire retardants (µg/L)	Total flavorings and fragrances (µg/L)	Total PAHs and combustion products (µg/L)	Total pesticides (µg/L)	Total plastics (µg/L)	Total solvents (µg/L)	Total sterols and stanols (µg/L)	Total stimulents (µg/L)	Total OMC (µg/L)	Instant-aneous stream-flow[1] (ft^3/s)	Instant-aneous load total OMC (mg/s)
6	Detections[2]	1	1	0	2	0	1	5	3	1	2	1	5	--	--
	Minimum[4]	0.60	0.37	--	0.02	--	0.20	0.42	0.08	0.01	0.32	0.46	0.43	9.6	0.58
	Maximum[4]	--	--	--	.12	--	--	4.33	.38	--	.75	--	4.73	104	4.51
	Average[4]	--	--	--	.07	--	--	1.27	.21	--	.53	--	1.96	40.3	1.58
	Median[4]	--	--	--	.07	--	--	.51	.16	--	.53	--	1.53	29.0	.70

[1]Streamflow calculated from an established stage-discharge relation for the site at the time of sampling.

[2]Number of samples with one or more detections of OMC.

[3]Total number of individual OMCs detected.

[4]Minimum, maximum, average and median values are calculated from data that may contain values that are estimated or less than the minimum reporting level.

Table 8. Summary of physical properties, constituent concentrations, and instantaneous loads and yields of selected constituents in stormflow samples, June 2005 through December 2008.

[ft^3/s, cubic feet per second; cm/storm, centimeters per storm duration; in/storm, inches per storm duration; NTU, nephelometric turbidity units; mg/L, milligrams per liter; µS/cm, microsiemens per centimeter at 25 degrees Celsius; °C, degrees Celsius; dissolved concentrations for filtered samples; total concentrations for unfiltered samples; N, nitrogen; P, phosphorus; BOD_5, biological oxygen demand, 5 days at 20 °C; COD, chemical oxygen demand; *E. coli*, *Escherichia coli*, MPN/100 mL, most probable number per 100 milliliters; col/100 mL, colonies per 100 milliliters; µg/L, micrograms per liter; g/s, grams per second; col/s, colonies per second; $kg/d/km^2$, kilograms per day per square kilometer; RL, reporting level for streamflow, precipitation, physical properties, BOD_5, COD, bacteria, and suspended sediment; LRL, laboratory reporting level for chloride, residue on evaporation, nutrients, and metals; MRL, minimum reporting level for cyanide; --, no data]

Site number (table 1; fig. 1)	Statistic	Streamflow[1] (ft^3/s)	Instantaneous streamflow[2] (ft^3/s)	Peak streamflow for storm event (ft^3/s)	Precipitation total (cm/storm)	Precipitation total (in./storm)	Turbidity (NTU)	Dissolved oxygen (mg/L)	pH (standard units)	Specific conductance, field (µS/cm)	Water temperature (°C)	Chloride, dissolved (mg/L)
All	Detections	81	73	86	85	85	50	13	87	87	62	78
	Minimum[8]	14	7	29	0.94	0.37	9	5.9	7.1	158	1.0	6.82
	Maximum[8]	8,030	3,690	14,100	17.55	6.91	1,170	12.8	8.2	1,720	28.3	463
	Average[8]	491	390	785	3.20	1.26	350	8.5	7.8	426	14.0	52.5
	Median[8]	134	158	254	2.72	1.07	305	7.6	7.8	347	14.6	26.3
	RL, LRL, or MRL	0.1	0.1	1	.01	.01	1	0.1	0.1	1	0.1	0.12
1	Detections	17	13	17	17	17	--	1	16	16	4	16
	Minimum[8]	20	9	55	.94	.37	--	6.0	7.1	172	5.8	6.82
	Maximum[8]	644	495	1,350	5.89	2.32	--	--	8.1	1,170	23.5	310
	Average[8]	135	125	329	3.10	1.22	--	--	7.7	364	15.7	42.3
	Median[8]	77	68	200	3.00	1.18	--	--	7.8	301	16.7	19.5
3	Detections	16	15	17	17	17	16	4	18	19	19	16
	Minimum[8]	72	27	86	1.24	.49	47	6.6	7.4	260	1.5	18.5
	Maximum[8]	5,500	1,560	9,390	16.97	6.68	1,170	11.4	8.2	1,070	24.9	231
	Average[8]	782	510	1,130	3.46	1.36	324	9.5	7.8	431	13.8	46.6
	Median[8]	368	366	454	2.34	.92	180	10.1	7.8	379	14.5	27.6
4	Detections	15	14	16	16	16	--	1	15	15	2	15
	Minimum[8]	14	7	36	1.17	.46	--	7.1	7.5	158	7.7	8.52
	Maximum[8]	1,000	512	1,600	5.18	2.04	--	--	8.2	1,340	20.1	338
	Average[8]	145	121	234	2.77	1.09	--	--	7.7	350	13.9	42.5
	Median[8]	45	41	89	2.32	.92	--	--	7.7	279	13.9	17.1
5	Detections	17	15	18	18	18	16	3	19	18	18	15
	Minimum[8]	21	9	29	1.24	.49	120	5.9	7.5	175	1.0	8.94
	Maximum[8]	770	439	1,400	5.72	2.25	1,030	7.6	8.2	1,720	25.2	463
	Average[8]	149	153	270	3.02	1.19	484	7.0	7.8	502	14.1	78.1
	Median[8]	83	66	175	2.79	1.10	440	7.5	7.8	387	14.3	33.2
6	Detections	16	16	18	17	17	18	4	19	19	19	16
	Minimum[8]	134	116	168	1.04	.41	9	6.6	7.3	244	1.4	15.0
	Maximum[8]	8,030	3,690	14,100	17.55	6.91	690	12.8	8.2	1,470	28.3	366
	Average[8]	1,260	949	1,900	3.61	1.42	254	9.7	7.8	462	13.8	54.1
	Median[8]	514	612	899	2.72	1.07	215	9.8	7.9	398	14.4	34.1

Table 8. Summary of physical properties, constituent concentrations, and instantaneous loads and yields of selected constituents in stormflow samples, June 2005 through December 2008.—Continued

[ft^3/s, cubic feet per second; cm/storm, centimeters per storm duration; in/storm, inches per storm duration; NTU, nephelometric turbidity units; mg/L, milligrams per liter; µS/cm, microsiemens per centimeter at 25 degrees Celsius; °C, degrees Celsius; dissolved concentrations for filtered samples; total concentrations for unfiltered samples; N, nitrogen; P, phosphorus; BOD_5, biological oxygen demand, 5 days at 20 °C; COD, chemical oxygen demand; *E. coli*, *Escherichia coli*, MPN/100 mL, most probable number per 100 milliliters; col/100 mL, colonies per 100 milliliters; µg/L, micrograms per liter; g/s, grams per second; col/s, colonies per second; $kg/d/km^2$, kilograms per day per square kilometer; RL, reporting level for streamflow, precipitation, physical properties, BOD_5, COD, bacteria, and suspended sediment; LRL, laboratory reporting level for chloride, residue on evaporation, nutrients, and metals; MRL, minimum reporting level for cyanide; --, no data]

Site number (table 1; fig. 1)	Statistic	Residue on evaporation at 180 °C, dissolved (mg/L)	Ammonia plus organic nitrogen, total (mg/L as N)	Ammonia, dissolved (mg/L as N)	Nitrite plus nitrate, dissolved (mg/L as N)	Nitrate, dissolved (mg/L as N)	Nitrite, dissolved (mg/L as N)	Total organic nitrogen (mg/L)	Total nitrogen[3] (mg/L)	Ortho-phosphate, dissolved (mg/L as P)	Phosphorus, dissolved (mg/L as P)	Phosphorus, total (mg/L as P)
All	Detections	78	80	57	80	80	80	80	80	78	80	80
	Minimum[8]	85	0.4	0.01	0.14	0.12	0.002	0.3	0.6	0.018	0.018	0.096
	Maximum[8]	924	13	1.4	1.5	1.46	.060	13	14	.450	.480	5.58
	Average[8]	251	2.6	.14	.52	.51	.019	2.5	3.2	.088	.100	1.00
	Median[8]	214	1.8	.09	.52	.50	.015	1.7	2.3	.072	.080	.642
	RL, LRL, or MRL	10	.1	.02	.04	.04	.002	.1	.1	.008	.04	.04
1	Detections	16	16	12	16	16	16	16	16	16	16	16
	Minimum[8]	109	.8	.01	.17	.16	.002	.7	1.3	.040	.070	.294
	Maximum[8]	660	13	1.4	1.5	1.46	.050	13	14	.450	.480	4.16
	Average[8]	233	3.5	.25	.66	.63	.022	3.3	4.2	.138	.162	1.07
	Median[8]	189	2.3	.12	.61	.57	.017	2.3	3.1	.113	.130	.787
3	Detections	16	17	12	17	17	17	17	17	17	17	17
	Minimum[8]	147	.7	.02	.14	.12	.008	.6	.8	.022	.020	.155
	Maximum[8]	574	7.5	.19	.77	.75	.030	7.3	8.2	.154	.170	3.42
	Average[8]	243	1.8	.10	.42	.41	.016	1.7	2.2	.057	.064	.644
	Median[8]	217	1.0	.09	.41	.39	.013	.9	1.4	.051	.060	.345
4	Detections	15	15	13	15	15	15	15	15	14	15	15
	Minimum[8]	85	.6	.02	.39	.35	.008	.5	1.0	.020	.040	.196
	Maximum[8]	708	13	.34	.83	.81	.050	12	13	.098	.110	5.58
	Average[8]	205	3.2	.13	.58	.55	.025	3.0	3.8	.062	.079	1.28
	Median[8]	165	2.2	.09	.56	.54	.020	2.1	2.8	.065	.080	.762
5	Detections	15	15	8	15	15	15	15	15	14	15	15
	Minimum[8]	97	.6	.01	.17	.15	.007	.5	.8	.051	.060	.227
	Maximum[8]	924	7.5	.21	.85	.82	.040	7.4	8.3	.292	.320	3.93
	Average[8]	305	2.9	.09	.51	.50	.018	2.8	3.4	.119	.125	1.27
	Median[8]	247	2.1	.06	.53	.50	.013	2.0	2.5	.104	.110	1.04
6	Detections	16	17	12	17	17	17	17	17	17	17	17
	Minimum[8]	150	.4	.01	.15	.14	.004	.3	.6	.018	.018	.096
	Maximum[8]	802	6.6	.19	1.2	1.09	.060	6.4	7.4	.172	.170	2.93
	Average[8]	268	2.0	.10	.47	.45	.016	1.9	2.5	.069	.076	.816
	Median[8]	226	1.4	.08	.42	.42	.010	1.4	1.9	.070	.070	.522

Table 8. Summary of physical properties, constituent concentrations, and instantaneous loads and yields of selected constituents in stormflow samples, June 2005 through December 2008.—Continued

[ft^3/s, cubic feet per second; cm/storm, centimeters per storm duration; in/storm, inches per storm duration; NTU, nephelometric turbidity units; mg/L, milligrams per liter; µS/cm, microsiemens per centimeter at 25 degrees Celsius; °C, degrees Celsius; dissolved concentrations for filtered samples; total concentrations for unfiltered samples; N, nitrogen; P, phosphorus; BOD_5, biological oxygen demand, 5 days at 20 °C; COD, chemical oxygen demand; *E. coli*, *Escherichia coli*, MPN/100 mL, most probable number per 100 milliliters; col/100 mL, colonies per 100 milliliters; µg/L, micrograms per liter; g/s, grams per second; col/s, colonies per second; $kg/d/km^2$, kilograms per day per square kilometer; RL, reporting level for streamflow, precipitation, physical properties, BOD_5, COD, bacteria, and suspended sediment; LRL, laboratory reporting level for chloride, residue on evaporation, nutrients, and metals; MRL, minimum reporting level for cyanide; --, no data]

Site number (table 1; fig. 1)	Statistic	Total BOD_5[4] (mg/L)	Total COD[4] (mg/L)	*E. coli*, (MPN/100 mL)[5]	Fecal coliform, (col/100 mL)	Total coliform, (MPN/100 mL)[5]	Aluminum, total (µg/L)	Arsenic, total (µg/L)	Cadmium, total (µg/L)	Chromium, total (µg/L)	Copper, total (µg/L)	Cyanide (mg/L)
All	Detections	83	86	76	80	74	77	77	34	77	74	3
	Minimum[8]	0.4	3	600	290	1,800	679	1.0	0.05	1.0	2.00	0.011
	Maximum[8]	28.8	461	120,000	210,000	8,700,000	45,700	19.2	5.60	70.0	144	.026
	Average[8]	6.5	77	21,200	24,500	1,030,000	9,660	6.2	1.63	14.5	24.0	.019
	Median[8]	5.5	55	12,000	13,000	430,000	5,440	5.2	1.15	8.9	16.3	.021
	RL, LRL, or MRL	.1	1	1	1	1	6	0.2	.06	0.4	4	.010
1	Detections	16	17	16	16	15	16	16	7	16	16	1
	Minimum[8]	1.7	3	3,200	3,200	24,000	799	1.0	.29	3.0	5.00	.011
	Maximum[8]	28.8	461	120,000	210,000	5,200,000	29,800	16.8	5.10	52.0	144	--
	Average[8]	10.6	103	34,900	50,700	1,400,000	7,140	6.2	1.83	12.8	31.7	--
	Median[8]	9.1	78	26,500	40,500	980,000	4,920	5.6	.90	8.4	18.5	--
3	Detections	18	18	16	17	16	16	16	7	16	15	1
	Minimum[8]	1.9	16	1,400	800	3,400	994	1.8	.10	2.0	2.00	.026
	Maximum[8]	8.3	155	88,000	32,000	2,200,000	33,200	13.4	2.50	48.0	69.0	--
	Average[8]	4.4	53	13,900	10,000	589,000	7,180	4.4	1.03	10.4	13.5	--
	Median[8]	4.2	40	5,800	3,600	295,000	3,160	3.2	.64	4.5	6.00	--
4	Detections	15	16	14	15	13	14	14	6	14	14	0
	Minimum[8]	1.1	3	2,100	3,000	16,000	2,030	3.0	.90	3.0	5.00	--
	Maximum[8]	20.8	438	77,000	100,000	8,700,000	45,700	19.2	5.60	70.0	136	--
	Average[8]	7.3	96	19,200	29,300	1,440,000	12,600	7.9	2.22	18.8	30.0	--
	Median[8]	7.0	70	13,000	20,000	680,000	9,160	7.1	1.30	13.5	20.3	--
5	Detections	16	17	15	15	14	15	15	7	15	15	0
	Minimum[8]	.9	4	1,600	2,700	19,000	1,420	2.0	.18	2.0	3.00	--
	Maximum[8]	16.1	174	100,000	92,000	3,800,000	38,300	15.0	4.10	53.0	75.0	--
	Average[8]	6.6	73	24,700	25,300	1,100,000	13,400	7.6	1.93	19.4	25.4	--
	Median[8]	6.2	61	19,000	16,000	710,000	11,400	7.4	1.90	15.0	19.3	--
6	Detections	18	18	15	17	16	16	16	7	16	14	1
	Minimum[8]	.4	10	600	290	1,800	679	1.7	.05	1.0	2.00	.021
	Maximum[8]	10.4	302	47,000	43,000	4,100,000	29,800	12.4	2.50	42.0	74.0	--
	Average[8]	4.4	65	12,600	9,180	710,600	8,550	5.4	1.23	11.9	18.8	--
	Median[8]	3.8	43	7,000	5,300	210,000	5,460	4.5	1.24	7.5	10.0	--

Table 8. Summary of physical properties, constituent concentrations, and instantaneous loads and yields of selected constituents in stormflow samples, June 2005 through December 2008.—Continued

[ft³/s, cubic feet per second; cm/storm, centimeters per storm duration; in/storm, inches per storm duration; NTU, nephelometric turbidity units; mg/L, milligrams per liter; µS/cm, microsiemens per centimeter at 25 degrees Celsius; °C, degrees Celsius; dissolved concentrations for filtered samples; total concentrations for unfiltered samples; N, nitrogen; P, phosphorus; BOD_5, biological oxygen demand, 5 days at 20 °C; COD, chemical oxygen demand; *E. coli*, *Escherichia coli*, MPN/100 mL, most probable number per 100 milliliters; col/100 mL, colonies per 100 milliliters; µg/L, micrograms per liter; g/s, grams per second; col/s, colonies per second; kg/d/km², kilograms per day per square kilometer; RL, reporting level for streamflow, precipitation, physical properties, BOD_5, COD, bacteria, and suspended sediment; LRL, laboratory reporting level for chloride, residue on evaporation, nutrients, and metals; MRL, minimum reporting level for cyanide; --, no data]

Site number (table 1; fig. 1)	Statistic	Lead, total (µg/L)	Mercury, total (µg/L)	Zinc, total (µg/L)	Suspended sediment (mg/L)	Load[6] chloride (g/s)	Load[6] nitrate (g/s as N)	Load[6] total organic nitrogen (g/s)	Load[6] total nitrogen (g/s)	Load[6] phosphorus, total (g/s as P)	Load[6] *E. coli* (1,000 col/s)	Load[6] suspended sediment (g/s)
All	Detections	77	71	77	75	78	80	80	80	80	76	75
	Minimum[8]	1.2	0.006	7.2	51	8.3	0.09	.17	.46	.12	16,600	51
	Maximum[8]	265	.300	813	8,570	4,460	146	1,250	1,460	666	86,400,000	964,000
	Average[8]	34.6	.053	132	1,150	436	7.93	58.6	68.7	26.2	4,330,000	36,300
	Median[8]	19.5	.033	87.0	552	155	1.86	7.20	9.44	2.66	5,560,000	2,330
	RL, LRL, or MRL	0.1	.01	2	1	--	--	--	--	--	--	--
1	Detections	16	16	16	15	16	16	16	16	16	16	15
	Minimum[8]	3.5	.011	24.0	68	14.9	.31	.78	1.36	.25	45,300	64
	Maximum[8]	265	.300	813	3,690	463	12.4	182	201	55.4	21,900,000	43,400
	Average[8]	56.1	.072	181	775	107	2.42	24.9	28.2	7.87	2,200,000	6,700
	Median[8]	32.7	.045	110	402	51.0	1.25	5.12	7.50	2.22	738,000	1,240
3	Detections	16	13	16	16	16	17	17	17	17	16	16
	Minimum[8]	2.0	.006	11.0	79	50.2	.47	1.22	1.83	.45	55,200	192
	Maximum[8]	95.7	.168	359	2,810	3,100	76.3	701	794	273	60,700,000	380,000
	Average[8]	16.2	.035	71.1	627	676	10.6	71.4	84.1	28.4	6,360,000	35,300
	Median[8]	6.0	.016	35.0	248	319	3.59	10.3	14.3	3.35	614,000	2,150
4	Detections	14	14	14	13	15	15	15	15	15	14	13
	Minimum[8]	4.4	.008	27.0	98	8.3	.20	.17	.56	.12	16,600	58
	Maximum[8]	206	.208	741	8,570	553	16.7	232	258	104	21,800,000	144,000
	Average[8]	43.3	.055	192	1,900	98.9	2.41	28.9	32.4	13.0	1,830,000	21,500
	Median[8]	26.0	.041	135	1,220	34.3	.62	1.67	2.22	.64	203,000	2,400
5	Detections	15	15	15	16	15	15	15	15	15	15	16
	Minimum[8]	3.2	.006	19.0	120	9.3	.09	.30	.46	.15	22,200	51
	Maximum[8]	122	.149	392	6,080	328	15.0	161	181	85.7	15,700,000	133,000
	Average[8]	38.5	.057	141	1,450	136	2.30	20.9	23.7	10.4	1,810,000	13,600
	Median[8]	27.2	.054	115	921	102	1.09	4.60	5.88	1.95	312,000	2,720
6	Detections	16	13	16	15	16	17	17	17	17	15	15
	Minimum[8]	1.2	.006	7.2	51	137	.60	1.29	2.37	.41	24,600	220
	Maximum[8]	81.0	.151	311	4,240	4,460	146	1,250	1,460	666	86,400,000	964,000
	Average[8]	20.2	.041	81.6	1,090	1,120	20.3	137	163	66.9	9,290,000	104,000
	Median[8]	11.6	.022	52.0	638	412	7.69	20.1	30.2	10.1	1,580,000	9,300

Table 8. Summary of physical properties, constituent concentrations, and instantaneous loads and yields of selected constituents in stormflow samples, June 2005 through December 2008.—Continued

[ft^3/s, cubic feet per second; cm/storm, centimeters per storm duration; in/storm, inches per storm duration; NTU, nephelometric turbidity units; mg/L, milligrams per liter; µS/cm, microsiemens per centimeter at 25 degrees Celsius; °C, degrees Celsius; dissolved concentrations for filtered samples; total concentrations for unfiltered samples; N, nitrogen; P, phosphorus; BOD_5, biological oxygen demand, 5 days at 20 °C; COD, chemical oxygen demand; *E. coli*, *Escherichia coli*, MPN/100 mL, most probable number per 100 milliliters; col/100 mL, colonies per 100 milliliters; µg/L, micrograms per liter; g/s, grams per second; col/s, colonies per second; $kg/d/km^2$, kilograms per day per square kilometer; RL, reporting level for streamflow, precipitation, physical properties, BOD_5, COD, bacteria, and suspended sediment; LRL, laboratory reporting level for chloride, residue on evaporation, nutrients, and metals; MRL, minimum reporting level for cyanide; --, no data]

Site number (table 1; fig. 1)	Statistic	Yield[7] chloride ($kg/d/km^2$)	Yield[7] nitrate ($kg/d/km^2$ as N)	Yield[7] total organic nitrogen ($kg/d/km^2$)	Yield[7] total nitrogen ($kg/d/km^2$)	Yield[7] phosphorus, total ($kg/d/km^2$ as P)	Yield[7] suspended sediment ($kg/d/km^2$)
All	Detections	78	80	80	80	80	75
	Minimum[8]	10.5	0.10	0.23	0.38	0.073	39
	Maximum[8]	3,690	111	1,550	1,720	693	962,000
	Average[8]	367	7.51	76.1	86.3	32.6	45,100
	Median[8]	161	2.92	10.0	14.3	3.57	3,690
	RL, LRL, or MRL	--	--	--	--	--	--
1	Detections	16	16	16	16	16	15
	Minimum[8]	53.3	1.12	2.82	4.88	.914	228
	Maximum[8]	1,660	44.5	654	720	199	156,000
	Average[8]	384	8.70	89.2	101	28.2	24,000
	Median[8]	183	4.50	18.4	26.9	7.98	4,430
3	Detections	16	17	17	17	17	16
	Minimum[8]	10.5	.10	.26	.38	.095	40
	Maximum[8]	650	16.0	147	167	57.2	79,700
	Average[8]	142	2.23	15.0	17.7	5.97	7,410
	Median[8]	66.8	.75	2.16	2.99	.703	451
4	Detections	15	15	15	15	15	13
	Minimum[8]	55.1	1.35	1.13	3.77	.778	389
	Maximum[8]	3,690	111	1,550	1,720	693	962,000
	Average[8]	660	16.1	193	216	86.9	143,000
	Median[8]	229	4.13	11.1	14.8	4.30	16,000
5	Detections	15	15	15	15	15	16
	Minimum[8]	31.6	.30	1.01	1.56	.506	174
	Maximum[8]	1,150	54.0	579	649	307	476,000
	Average[8]	476	8.11	73.7	83.5	36.6	48,000
	Median[8]	348	3.71	16.5	21.1	7.01	9,520

Table 8. Summary of physical properties, constituent concentrations, and instantaneous loads and yields of selected constituents in stormflow samples, June 2005 through December 2008.—Continued

[ft^3/s, cubic feet per second; cm/storm, centimeters per storm duration; in/storm, inches per storm duration; NTU, nephelometric turbidity units; mg/L, milligrams per liter; µS/cm, microsiemens per centimeter at 25 degrees Celsius; °C, degrees Celsius; dissolved concentrations for filtered samples; total concentrations for unfiltered samples; N, nitrogen; P, phosphorus; BOD_5, biological oxygen demand, 5 days at 20 °C; COD, chemical oxygen demand; *E. coli*, *Escherichia coli*, MPN/100 mL, most probable number per 100 milliliters; col/100 mL, colonies per 100 milliliters; µg/L, micrograms per liter; g/s, grams per second; col/s, colonies per second; $kg/d/km^2$, kilograms per day per square kilometer; RL, reporting level for streamflow, precipitation, physical properties, BOD_5, COD, bacteria, and suspended sediment; LRL, laboratory reporting level for chloride, residue on evaporation, nutrients, and metals; MRL, minimum reporting level for cyanide; --, no data]

Site number (table 1; fig. 1)	Statistic	Yield[7] chloride ($kg/d/km^2$)	Yield[7] nitrate ($kg/d/km^2$ as N)	Yield[7] total organic nitrogen ($kg/d/km^2$)	Yield[7] total nitrogen ($kg/d/km^2$)	Yield[7] phosphorus, total ($kg/d/km^2$ as P)	Yield[7] suspended sediment ($kg/d/km^2$)
6	Detections	16	17	17	17	17	15
	Minimum[8]	24.1	.11	.23	.42	.073	39
	Maximum[8]	787	25.7	221	257	118	170,000
	Average[8]	198	3.58	24.2	28.8	11.8	18,400
	Median[8]	72.8	1.36	3.55	5.33	1.79	1,640

[1]Average streamflow for the sampled storm interval used in calculations of loads and yields.

[2]Streamflow calculated from an established stage-discharge relation for the site at the time the grab samples were collected, including BOD_5 and cyanide (beginning November 2008).

[3]Total nitrogen equals ammonia plus nitrate plus nitrite plus organic nitrogen.

[4]Analyses and reported results from the laboratory at the City of Independence Rock Creek Wastewater Teatment Plant.

[5]For the purposes of this report, most probable number per 100 milliliters is considered to be comparable to colonies per 100 milliliters.

[6]Loads are instantaneous loads calculated from multiplying the instantaneous streamflow, sampled concentration, and a constant to standardize units.

[7]Yields are instantaneous yields calculated by dividing the instantaneous load by the drainage area above the sample collection point and multiplying by a constant to standardize units.

[8]Minimum, maximum, average and median values are calculated from data that may contain values that are estimated or less than the method detection level.

Table 9. Summary of constituent concentrations and instantaneous loads of common organic micro-constituents in stormflow samples, June 2005 through December 2008.

[µg/L, micrograms per liter; PAHs, polyaromatic hydrocarbons; OMC, common organic micro-constituents; ft^3/s, cubic feet per second; mg/s, milligrams per second; --, no data]

Site number (table 1; fig. 1)	Statistic	Total anti-oxidants (µg/L)	Total detergents (µg/L)	Total disinfectants (µg/L)	Total fire retardants (µg/L)	Total flavorings and fragrances (µg/L)	Total PAHs and combustion products (µg/L)	Total pesticides (µg/L)	Total plastics (µg/L)	Total solvents (µg/L)	Total sterols and stanols (µg/L)	Total stimulents (µg/L)	Total OMC (µg/L)	Stream-flow[1] (ft^3/s)	Instant-aneous load total OMC (mg/s)
All	Detections[2]	26	51	22	62	48	75	76	71	30	62	69	76	--	--
	Total detections[3]	26	103	25	106	102	471	548	186	31	132	75	1,805	--	--
	Minimum[4]	0.09	0.11	0.05	0.02	0.01	0.02	0.17	0.03	0.01	0.26	0.06	0.27	14	1.08
	Maximum[4]	.60	5.26	.78	2.17	2.55	12.5	22.6	6.41	.10	30.7	3.32	44.8	8,030	860
	Average[4]	.29	1.26	.20	.16	.28	1.57	3.79	.83	.03	3.01	.37	10.2	505	87.4
	Median[4]	.23	.80	.14	.11	.22	.91	2.22	.57	.03	1.34	.20	6.82	139	34.8
1	Detections[2]	9	13	8	14	14	16	16	15	9	16	14	16	--	--
	Minimum[4]	.14	.11	.06	.04	0.09	.64	1.14	.39	.02	.59	.06	4.70	20	7.97
	Maximum[4]	.59	5.26	.78	.30	2.55	12.3	21.6	6.41	.10	30.7	3.32	44.8	644	359
	Average[4]	.34	1.82	.19	.15	.26	2.39	5.49	1.23	.03	4.84	.77	16.2	201	76.0
	Median[4]	.34	1.64	.09	.18	.31	1.61	2.87	.71	.03	4.01	.42	15.6	75	42.1
3	Detections[2]	2	11	3	12	7	15	16	14	4	12	15	16	--	--
	Minimum[4]	.20	.24	.05	.04	.01	.28	.77	.14	.01	.26	.06	2.41	72	9.84
	Maximum[4]	.23	2.68	.48	.31	.22	2.70	4.04	1.34	.03	3.46	.63	9.40	5,500	774
	Average[4]	.21	.96	.24	.12	.11	.76	2.44	.63	.02	1.13	.20	5.62	780	116
	Median[4]	.21	.80	0.1	.12	.11	.51	2.26	.62	.02	0.73	.17	4.95	368	51.9
4	Detections[2]	5	9	4	11	8	13	13	13	5	11	12	13	--	--
	Minimum[4]	.21	.15	.11	.05	.01	.21	.29	.15	.01	.58	.11	1.36	14	1.08
	Maximum[4]	.48	2.33	.54	.31	.58	12.5	22.6	2.58	.04	7.14	.69	29.5	1,000	329
	Average[4]	.31	1.08	.26	.16	.23	2.68	4.86	1.22	.03	2.30	.31	12.2	161	51.9
	Median[4]	.24	.84	.19	.10	.23	1.34	2.10	1.13	.03	1.40	.23	10.5	45	24.3
5	Detections[2]	7	10	5	13	12	16	16	15	8	13	15	16	--	--
	Minimum[4]	.16	.34	.08	.02	.02	.03	.81	.07	.02	.47	.08	2.59	21	2.68
	Maximum[4]	.60	3.21	.28	2.17	.50	4.79	10.2	2.33	.07	10.8	.79	26.8	770	97.0
	Average[4]	.29	1.55	.14	.27	.26	1.44	3.31	.62	.03	2.51	.30	9.22	151	29.7
	Median[4]	.23	1.30	.11	.09	.28	1.09	2.34	.44	.03	1.69	.25	7.86	79	20.0

Table 9. Summary of constituent concentrations and instantaneous loads of common organic micro-constituents in stormflow samples, June 2005 through December 2008.—Continued

[µg/L, micrograms per liter; PAHs, polyaromatic hydrocarbons; OMC, common organic micro-constituents; ft^3/s, cubic feet per second; mg/s, milligrams per second; --, no data]

Site number (table 1; fig. 1)	Statistic	Total anti-oxidants (µg/L)	Total detergents (µg/L)	Total disinfectants (µg/L)	Total fire retardants (µg/L)	Total flavorings and fragrances (µg/L)	Total PAHs and combustion products (µg/L)	Total pesticides (µg/L)	Total plastics (µg/L)	Total solvents (µg/L)	Total sterols and stanols (µg/L)	Total stimulents (µg/L)	Total OMC (µg/L)	Stream-flow[1] (ft^3/s)	Instant-aneous load total OMC (mg/s)
6	Detections[2]	3	8	2	12	7	15	15	14	4	10	13	15	--	--
	Minimum[4]	0.09	0.22	0.06	0.05	0.01	0.02	0.17	0.03	0.02	0.38	0.07	0.27	134	6.52
	Maximum[4]	.14	.64	.16	.16	0.45	3.67	12.3	.79	.05	1.24	.42	14.5	8,030	860
	Average[4]	.11	.42	.11	.09	.21	.63	2.42	.40	.03	.81	.15	4.54	1,280	165
	Median[4]	.11	.39	.11	.08	.22	.51	1.48	.40	.03	.76	.12	3.84	520	64.5

[1]Average streamflow for the sampled storm interval.

[2]Number of samples with one or more detections of OMC.

[3]Total number of individual OMCs detected.

[4]Minimum, maximum, average and median values are calculated from data that may contain values that are estimated or less than the minimum reporting level.

Table 11. Selected constituents and dissolved metals concentrations in stormflow, October 17, 2007.

[ft^3/s, cubic feet per second; NTU, nephelometric turbidity units; µS/cm, microsiemens per centimeter at 25 degrees Celsius; °C, degrees Celsius; dissolved concentrations for filtered samples; mg/L, milligrams per liter; total concentrations for unfiltered samples; N, nitrogen; P, phosphorus; µg/L, micrograms per liter; --, no data; E, estimated; A, average; <, less than; M, presence verified not quantified]

Site number (table 1; fig. 1)	Sample start date	Sample start time	Streamflow[1] (ft^3/s)	Instantaneous streamflow[2] (ft^3/s)	Peak streamflow for storm event (ft^3/s)	Turbidity (NTU)	pH, field (standard units)	pH, laboratory (standard units)	Specific conductance, laboratory (µS/cm)	Specific conductance, field (µS/cm)	Water temperature (°C)	Gage height (feet)
1	10/17/2007	1300	179	--	447	--	8	7.8	237	232	--	--
3	10/17/2007	2000	--	946	1,100	E780	7.9	7.8	293	271	16.6	33.52
4	10/17/2007	1330	133	--	294	--	7.9	8.1	209	201	--	--
5	10/17/2007	1700	404	--	575	A800	8	7.9	186	175	A16.5	--
6	10/17/2007	1800	1,810	--	1,980	A690	8	7.8	272	267	A16.4	--

Site number (table 1; fig. 1)	Sample start date	Sample start time	Residue on evaporation at 180 °C, dissolved (mg/L)	Sodium, dissolved (mg/L)	Sodium, total (mg/L)	Chloride, dissolved (mg/L)	Ammonia plus organic nitrogen, total (mg/L as N)	Ammonia, dissolved (mg/L as N)	Nitrite plus nitrate, dissolved (mg/L as N)	Nitrate, dissolved (mg/L as N)	Nitrite, dissolved (mg/L as N)	Total organic nitrogen (mg/L)
1	10/17/2007	1300	140	9.38	9.3	13.1	2.6	0.073	0.57	0.56	0.013	2.5
3	10/17/2007	2000	159	13.6	14.2	18.6	2.7	.066	.61	.60	.019	2.7
4	10/17/2007	1330	120	7.55	8.0	11.6	3.2	.089	.57	.56	.015	3.1
5	10/17/2007	1700	97	7.11	7.8	8.94	5.9	.052	.37	.36	.011	5.8
6	10/17/2007	1800	150	13.0	13.8	17.9	2.9	.061	.62	.60	.018	2.9

Site number (table 1; fig. 1)	Sample start date	Sample start time	Total nitrogen[3] (mg/L)	Ortho-phosphate, dissolved (mg/L)	Ortho-phosphate, dissolved (mg/L as P)	Phosphorus, dissolved (mg/L as P)	Phosphorus, total (mg/L as P)	Aluminum, dissolved (µg/L)	Aluminum, total (µg/L)	Antimony, dissolved (µg/L)	Arsenic, total (µg/L)	Barium, dissolved (µg/L)
1	10/17/2007	1300	3.2	0.395	0.129	0.12	0.86	2.6	6,570	0.27	5.9	42
3	10/17/2007	2000	3.3	.249	.081	.08	1.32	1.8	21,100	.75	7.6	61
4	10/17/2007	1330	3.8	.299	.098	.09	1.45	2.3	15,500	.24	9.9	55
5	10/17/2007	1700	6.2	.346	.113	.10	2.92	4.1	30,000	.27	13.1	41
6	10/17/2007	1800	3.5	.285	.093	.08	1.41	2.5	17,500	.51	9.0	65

Table 11. Selected constituents and dissolved metals concentrations in stormflow, October 17, 2007.—Continued

[ft^3/s, cubic feet per second; NTU, nephelometric turbidity units; µS/cm, microsiemens per centimeter at 25 degrees Celsius; °C, degrees Celsius; dissolved concentrations for filtered samples; mg/L, milligrams per liter; total concentrations for unfiltered samples; N, nitrogen; P, phosphorus; µg/L, micrograms per liter; --, no data; E, estimated; A, average; <, less than; M, presence verified not quantified]

Site number (table 1; fig. 1)	Sample start date	Sample start time	Beryllium, dissolved (µg/L)	Cadmium, dissolved (µg/L)	Cadmium, total (µg/L)	Chromium, dissolved (µg/L)	Chromium, total (µg/L)	Cobalt, dissolved (µg/L)	Copper, dissolved (µg/L)	Copper, total (µg/L)	Cyanide (mg/L)	Lead, dissolved (µg/L)
1	10/17/2007	1300	<0.01	<0.04	M	0.57	11	0.05	1.9	27	0.011	E.07
3	10/17/2007	2000	<.01	E.02	1	.16	28	.09	1.6	28	<.010	E.05
4	10/17/2007	1330	<.01	<.04	1	.26	21	.14	1.6	32	<.010	E.05
5	10/17/2007	1700	<.01	E.02	3	.26	40	.08	1.4	61	<.010	E.06
6	10/17/2007	1800	<.01	<.04	1	.13	23	.08	1.5	31	<.010	E.04

Site number (table 1; fig. 1)	Sample start date	Sample start time	Lead, total (µg/L)	Manganese, dissolved (µg/L)	Mercury, total (µg/L)	Molybdenum, dissolved (µg/L)	Nickel, dissolved (µg/L)	Silver, dissolved (µg/L)	Zinc, dissolved (µg/L)	Zinc, total (µg/L)	Uranium (natural), dissolved (µg/L)	Suspended sediment (mg/L)
1	10/17/2007	1300	50.5	0.6	0.064	1.0	0.92	<0.1	E1.3	151	0.36	574
3	10/17/2007	2000	35.0	3.4	.063	1.8	1.3	<.1	E1.2	153	.69	1,840
4	10/17/2007	1330	46.2	13.5	.076	1.2	1.3	<.1	E1.6	212	.44	2,050
5	10/17/2007	1700	98.0	.9	.128	1.5	1.2	<.1	E1.3	333	.48	4,410
6	10/17/2007	1800	40.0	.4	.071	2.0	1.3	<.1	E.90	161	.71	1,930

[1]Average streamflow for the sampled storm interval.

[2]Streamflow calculated from an established stage-discharge relation for site 3 at the time the grab sample was obtained on October 17, 2007.

[3]Total nitrogen equals ammonia plus nitrate plus inorganic nitrogen.

Table 12. Summary of dry-weather screening constituent detections in streams in Independence, Missouri, 2006 through 2008.

[mg/L, milligrams per liter; All, combination of all data for all streams; <, less than; >, greater than; EDL, estimated detection limit; MDL, method detection limit; M values, constituent detected but not quantified; results are semi-quantitative]

Sample year	Statistic	Total chlorine (mg/L)	Total dissolved copper (mg/L)	Phenols (mg/L)	Anionic surfactants (mg/L)
	All basins (table 1; fig. 2)				
2006–2008	Analyses	536	536	524	535
	Detections[1]	495	131	225	477
	Percent deleted[2]	0.6	3.4	0	0.2
	Minimum[3]	<.05	<0.05	<0.005	<.010
	Maximum[3]	7.00	.18	>.200	5.000
	Average[3]	.07	<.05	<.005	.016
	Median[3]	.05	<.05	<.005	<.010
	EDL[4]	.02	.04	.002	.002
	MDL[5]	.05	.05	.005	.010
	Percent M values[6]	49.3	12.7	21.9	45.2
	Percent above MDL	43.1	11.8	21.0	43.9
	Rock Creek Basin (table 1; fig. 2)				
2006	Analyses	54	54	46	54
	Detections[1]	46	5	24	53
	Minimum[3]	<.05	<.05	<.005	<.010
	Maximum[3]	2.06	.18	>.200	>.275
	Average[3]	.08	[7]<.05	.017	.019
	Median[3]	<.05	[7]<.05	<.005	.010
	Percent M values[6]	48.1	5.6	17.4	50.0
	Percent above MDL	37.0	3.7	34.8	48.1

Sample year	Statistic	Total chlorine (mg/L)	Total dissolved copper (mg/L)	Phenols (mg/L)	Anionic surfactants (mg/L)
	Crackerneck Creek Basin (table 1; fig. 2)				
2006	Analyses	31	31	31	31
	Detections[1]	28	1	19	24
	Minimum[3]	<0.05	<0.05	<0.005	<0.010
	Maximum[3]	.15	.05	.045	.218
	Average[3]	<.05	[7]<.05	.007	.017
	Median[3]	<.05	[7]<.05	<.005	<.010
	Percent M values[6]	74.2	3.2	25.8	35.5
	Percent above MDL	16.1	0	35.5	41.9
	Spring Branch Creek (table 1; fig. 2)				
2006	Analyses	52	52	52	51
	Detections[1]	49	10	23	31
	Minimum[3]	<.05	<.05	<.005	<.010
	Maximum[3]	.12	.11	.017	.065
	Average[3]	.05	<.05	<.005	.010
	Median[3]	.05	<.05	<.005	<.010
	Percent M values[6]	67.3	11.5	26.9	35.3
	Percent above MDL	26.9	7.7	17.3	25.5

Table 12. Summary of dry-weather screening constituent detections in streams in Independence, Missouri, 2006 through 2008.—Continued

[mg/L, milligrams per liter; All, combination of all data for all streams; <, less than; >, greater than; EDL, estimated detection limit; MDL, method detection limit; M values, constituent detected but not quantified; results are semi-quantitative]

Sample year	Statistic	Total chlorine (mg/L)	Total dissolved copper (mg/L)	Phenols (mg/L)	Anionic surfactants (mg/L)
		Rock Creek (table 1; fig. 2)			
2007	Analyses	52	52	52	52
	Detections[1]	45	11	19	49
	Minimum[3]	<.05	<.05	<.005	<.010
	Maximum[3]	1.63	.11	.013	.090
	Average[3]	.12	<.05	<.005	<.010
	Median[3]	.07	<.05	<.005	<.010
	Percent M values[6]	19.2	13.5	17.3	69.2
	Percent above MDL	67.3	7.7	19.2	25.0
		Sugar Creek (table 1; fig. 2)			
2007	Analyses	8	8	8	8
	Detections[1]	8	2	6	8
	Minimum[3]	.06	<.05	<.005	<.010
	Maximum[3]	1.55	<.05	.015	.025
	Average[3]	.28	[7]<.05	.005	.012
	Median[3]	.11	[7]<.05	<.005	.011
	Percent M values[6]	0	25.0	50.0	50.0
	Percent above MDL	100.0	0	25.0	50.0
		Adair Creek (table 1; fig. 2)			
2007	Analyses	75	75	75	75
	Detections[1]	66	28	28	61
	Minimum[3]	<.05	<.05	<.005	<.010
	Maximum[3]	1.89	.11	.012	.278
	Average[3]	.07	<.05	<.005	.011
	Median[3]	.05	<.05	<.005	<.010
	Percent M values[6]	38.7	18.7	14.7	52.0
	Percent above MDL	49.3	18.7	22.7	29.3
		Rock Creek (table 1; fig. 2)			
2008	Analyses	87	87	87	87
	Detections[1]	83	32	24	87
	Minimum[3]	<.05	<.05	<.005	<.010
	Maximum[3]	.14	.14	.017	.211
	Average[3]	.05	<.05	<.005	.022
	Median[3]	.05	<.05	<.005	.015
	Percent M values[6]	56.3	14.9	14.9	29.9
	Percent above MDL	39.1	21.8	12.6	70.1

Table 12. Summary of dry-weather screening constituent detections in streams in Independence, Missouri, 2006 through 2008.—Continued

[mg/L, milligrams per liter; All, combination of all data for all streams; <, less than; >, greater than; EDL, estimated detection limit; MDL, method detection limit; M values, constituent detected but not quantified; results are semi-quantitative]

Sample year	Statistic	Total chlorine (mg/L)	Total dissolved copper (mg/L)	Phenols (mg/L)	Anionic surfactants (mg/L)	Sample year	Statistic	Total chlorine (mg/L)	Total dissolved copper (mg/L)	Phenols (mg/L)	Anionic surfactants (mg/L)
	Mill Creek (table 1; fig. 2)						Adair Creek (table 1; fig. 2)				
2007	Analyses	54	54	50	54	2008	Analyses	55	55	55	55
	Detections[1]	52	12	25	49		Detections[1]	52	17	23	55
	Minimum[3]	<.05	<.05	<.005	<.010		Minimum[3]	<.05	<.05	<.005	<.010
	Maximum[3]	7.00	.08	.048	5.000		Maximum[3]	.11	.09	.014	.221
	Average[3]	.09	<.05	<.005	.025		Average[3]	.05	<.05	<.005	.024
	Median[3]	.06	<.05	<.005	<.010		Median[3]	<.05	<.05	<.005	.017
	Percent M values[6]	33.3	14.8	32.0	50.0		Percent M values[6]	60.0	18.2	27.3	16.4
	Percent above MDL	63.0	7.4	18.0	40.7		Percent above MDL	34.5	12.7	14.5	83.6
	Burr Oak Creek (table 1; fig. 2)						Bundschu Creek (table 1; fig. 2)				
2008	Analyses	22	22	22	22	2008	Analyses	46	46	46	46
	Detections[1]	22	3	12	16		Detections[1]	43	10	21	44
	Minimum[3]	<.05	<.05	<.005	<.010		Minimum[3]	<.05	.05	<.005	<.010
	Maximum[3]	.15	.06	.010	.018		Maximum[3]	011	.07	.019	.023
	Average[3]	.06	<.05	<.005	<.010		Average[3]	.05	<.05	<.005	<.010
	Median[3]	.05	<.05	<.005	<.010		Median[3]	<0.05	<.05	<.005	<.010
	Percent M values[6]	54.5	4.5	27.3	59.1		Percent M values[6]	60.9	6.5	23.9	69.6
	Percent above MDL	45.5	9.1	27.3	13.6		Percent above MDL	32.6	15.2	21.7	26.1

[1]Number of detections is the number of samples for each analyte with concentrations greater than the EDL.

[2]Values deleted due to suspected interferences.

[3]Minimum, maximum, average and median values are calculated from data that may contain values that are estimated or less than the provisional method detection limit.

[4]The EDL is determined by Hach Company©, the manufacturer of the analyte tests.

[5]Provisional MDL is determined by a comparison of the results of the environmental samples with the replicate and duplicate samples.

[6]M values are values that are between the EDL and MDL for each analyte; values are given in percentage of total analyses.

[7]The number of censored values less than the MDL (97 percent of samples) preclude the calculation of an average and median for these samples; therefore, the averages and medians are less than the MDL.

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